ENGINEERING CASE LIBRARY

ECL 250

CENTER INDUSTRIES CORPORATION

Leonard Anderson is an engineer at a small manufacturing company employing handicapped workers. He is asked to design and implement modifications on a commercially available tube beading machine.so that Pat K., a young man afflicted with celebral palsy, can operate it. Making use of tests and observations of Pat's capabilities, Leonard modifies the machine so that Pat can achieve the required production rate and become a regular employee.

Prepared by J. A. Alic at Wichita University, August 1977, with the support of grant No. SER77-02451 from the National Science Foundation. The cooperation of Center Industries Corporation, and of the Rehabilitation Engineering Center at Wichita State University, in particular Leonard Anderson, is greatly appreciated.

CENTER INDUSTRIES CORPORATION (A)

In October 1976, Leonard Anderson began a new job as Design Engineer with the Rehabilitation Engineering Center (REC) at Wichita State University. The REC provides engineering services to Center Industries Corporation, also located in Wichita, Kansas. One of Leonard's first assignments was to adapt a machine used at Center Industries for forming a ridge in a steel tube so that it could be operated by Pat K----, a young man severely handicapped by cerebral palsy. As you work through this project, you should imagine yourself in Leonard Anderson's place. You will be given much of the information he had to work with, and asked to solve many of the same problems he had to solve. These problems will be posed for you in the sections below entitled "Instruction." The following section will often give Leonard's own solution to that problem. In reading these, you will see the work of an experienced engineer. This does not, however, necessarily mean that the way Leonard Anderson worked through this project is the only way or the best way. It is one way among many. The case also includes comments by the writer, and information important for the project to which you may not have been previously exposed.

BACKGROUND

Center Industries Corporation (CIC) was established in Wichita, Kansas, in 1974 as a nonprofit company employing the handicapped. A light manufacturing firm, CIC produces license plates for the state of Kansas, as well as components and subassemblies for other companies. Manufacturing capabilities at CIC include sheet metal forming, machining operations, and assembly. CIC itself subcontracts some work such as casting and plating. In addition to its manufacturing operations, CIC operates a training program for the

handicapped. Located in the same building, the trainees may "graduate" to regular, paying production jobs when they have shown themselves capable.

Portions of CIC's activities are funded by grants from state and federal government. However, the manufacturing operations are intended as a profit-making entity. Employees--three-quarters of whom are handicapped--earn competitive wages. Workers without disabilities are hired for jobs requiring skills not available in the current pool of handicapped.

By the summer of 1977, CIC employed about 50 people, was doing subcontract work for 20 different customers, and grossing close to $70,000 per month. The eventual goal was to employ as many as 200 handicapped workers and make a profit on the manufacturing operations which could be used to support other CIC activities such as the training program.

Many, though not all, of the handicapped employees at CIC have cerebral palsy. Cerebral plasy is a disease of the central nervous system which results in various degrees of paralysis and spasticity--in general, poor psychomotor abilities. A typical manifestation might involve poor coordination, poor muscle control (spasmodic movements), and a limited range of motion for the afflicted limbs. Such disabilities can make typical manufacturing jobs difficult; even unskilled factory work--such as on assembly lines--often requires good manual dexterity and a learning period. In contrast, common, everyday tasks such as driving a nail or sawing a board may be impossible for people with more than mild forms of cerebral palsy. For those with such disabilities to perform competitively at CIC--allowing the company to meet its cost, quality, and delivery targets--often requires that the REC engineering staff modify both machines and processes to match their capabilities.

INTRODUCTION

Leonard Anderson went to work for the Rehabilitation Engineering Center as a Design Engineer in October 1976. His primary responsibility was to design modifications to machines so that they could be operated by CIC's handicapped employees. Leonard had 20 years experience with the Boeing Company in Wichita, and had also operated a small company of his own before coming to the REC. While working at Boeing, Leonard had earned bachelor's and master's degrees at Wichita State University. He described his work by saying, "Although my title is Design Engineer, it could almost be Gadget Engineer. Much of our work in adapting machines to the handicapped is gadgeteering. I found my background in mechanical testing at Boeing to be very helpful. Testing is much the same--every problem is different, and you have to find ways to move things around and apply forces."

At present, the REC engineering staff also includes a Manufacturing Engineer, Charles Schlicher, who is assigned full time to Center Industries. While Leonard's job involves primarily the adaptation or modification of machines, Mr. Schlicher is concerned more with maintenance, tooling, plant layout, process development, and so on. For example, CIC has two numerically controlled lathes. These lathes are operated by programming their operations much as a computer is programmed. Then, once programmed, the operations are automatic, rather then requiring manual control. Programming these lathes is one of Mr. Schilcher's responsibilities.

In addition to such relatively sophisticated equipment, other machine tools[1] at CIC include drill presses and milling machines. Among the pieces

[1]Machine tools shape parts by cutting material away in the form of chips or shavings.

of metalworking[2] equipment are various types of presses, as well as a coil-winder for making springs. Some of this equipment is owned by CIC; other machines are loaned or leased by firms which have contracts with CIC.

In his work, Leonard can now call upon a toolmaker, a mechanic, and several other skilled craftsmen for help. However, in 1976 when he began the tube beader project, none of this assistance was available. Both Leonard and Mr. Schlicher report to Roy Norris, the REC's Director of Technical Staff. Roy is an electrical engineer who participates directly in many of the machine modification projects.

THE PROBLEM

One of the first projects Leonard Anderson was given when he began working with Center Industries was the modification of a tube beading machine so that it could be operated by a severely handicapped employee.

Leonard recalled, "This was basically a management decision. The tube beader was being run by an able-bodied operator. Management wanted this machine adapted so that Pat K--- could handle it. Pat was then in the training program and one of our most severely handicapped people."

The "tube beader" forms a raised ridge or bead around the circumference of a piece of steel tubing. The machine is actually a Parker Power Flarer, Model 232B, made by Parker-Hannifin Corporation in Cleveland. In addition to beading tubing, the Model 232B can be used to form flares for various types of tube fittings and to square and deburr the ends of tubing.

In CIC's application, the beaded steel tube becomes part of a telescoping strut used to prop open camper tops on pickup trucks. The complete strut as

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[2]Metalworking or metalforming involves shaping a part by the application of force. For example, license plates are made at CIC by embossing the letters and numerals in a press using sets of male and female dies.

well as a pair of tubes before and after beading are shown in Exhibit A-1. The assembled strut at the bottom is in the closed position. A spring inside helps to lift the camper top, which can then be held in the raised position by latching the struts (two, one on each side of the pickup bed, are used).

Manufacture of the complete strut assembly had been contracted to CIC. Steel tubing was purchased cut to length, as shown at the top in Exhibit A-1. One of the first operations was to form the bead. Later operations included further blanking[3] and forming steps on the tubes, winding the springs, and assembling the struts. The strut line is one of CIC's bigger contracts, employing 10 people. Peak production is 1100 struts per day.

The Parker Power Flarer forms the bead in the steel tube by forcing the metal to flow outwards into a female die. The force is applied by a small steel wheel, called the beader, which is inserted within the tube and then moved outwards and driven around the circumference of the tube by an electric motor. Leonard said, "I noticed that even with an able-bodied operator, a simple fixture[4] had been added to make the job easier. The operator had to pick up and insert the tube and then operate two levers while still holding the tube. The fixture was a steel strap bolted on to help him get the tube in the right place and hold it there. One thing I quickly found out on this job is that machines are not necessarily designed to make things easy for the operator. Many of the modifications we make so that our handicappers can use a machine would help <u>anyone</u> working that machine."

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[3] Blanking is the process of cutting a hole (of any shape) with a set of dies. Optionally, the blanking can precede forming the bead.

[4] A fixture locates or aids in locating a workpiece with respect to forming or cutting tools.

Instruction A

1. Define Leonard Anderson's problem in at least three different ways.
2. Choose the problem definition which you feel is most appropriate to the circumstances and explain why you feel it is the best definition.

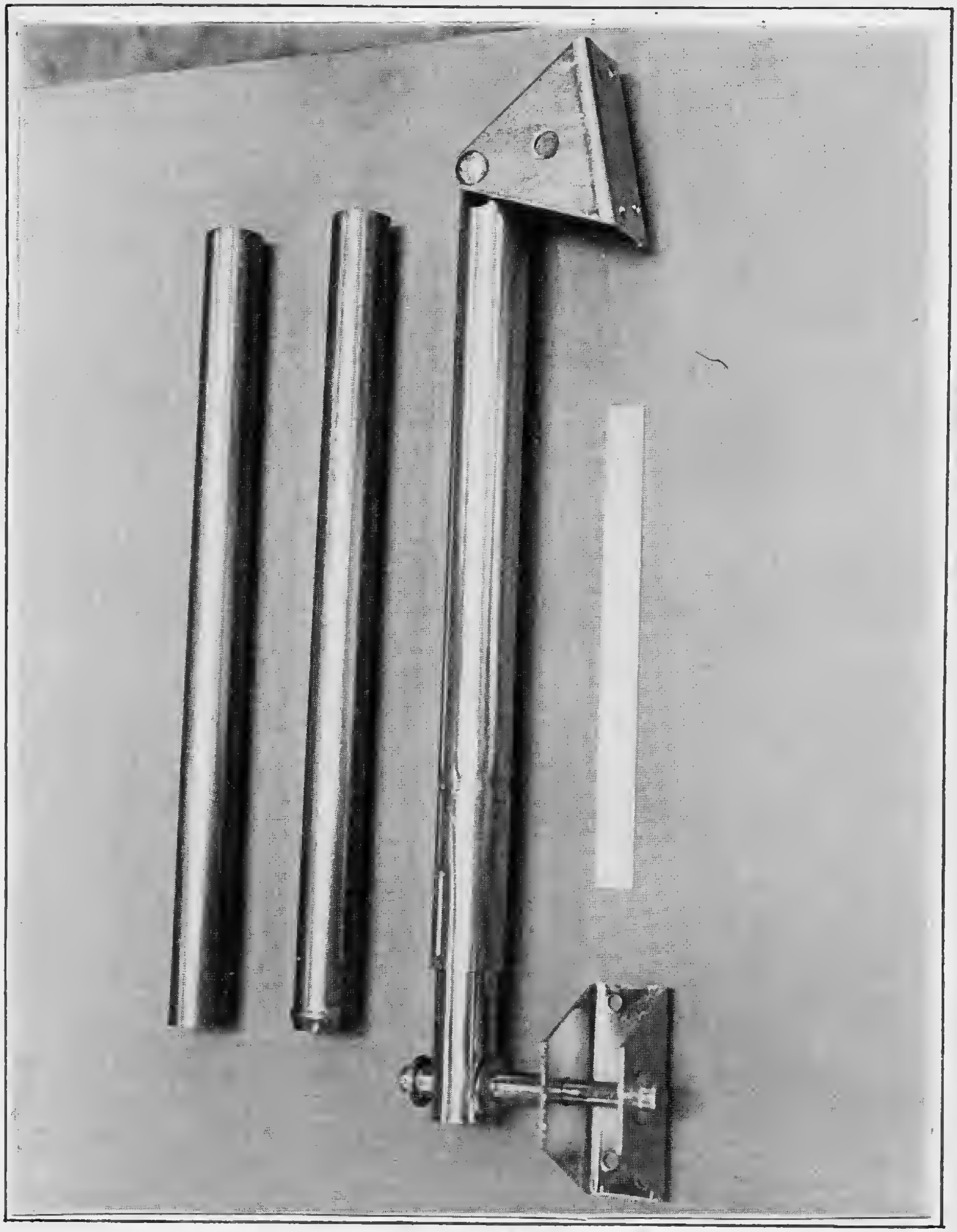

Exhibit A-1. Steel Tubes Before (top) and After(middle) Beading, with Completed Strut Assembly (Bottom).

CENTER INDUSTRIES CORPORATION (B)

Extremes of generality versus specificity in problem definition for this situation might be:

Very General

Find a way to lift up and hold camper tops for pickup trucks (which could be profitably manufactured by Center Industries).

Very Specific

Modify, at low cost, the existing Parker Power Flarer so that an operator with the particular capabilities of Pat K. can produce at least 1100 beaded tubes per day.

Other possible problem definitions might focus on such questions as (1) whether the tube beading operation should be set up specifically for Pat K. or for a range of possible handicapped operators with various disabilities and (2) whether the Parker Power Flarer should be retained or replaced by another machine which might be easier for a handicapped employee to run.

Leonard Anderson's working problem definition--which he probably did not explicitly formulate--appears to have been close to the one above labelled "Very Specific." Leonard said, "Our usual practice on machine modifications is to set them up for a particular client.[1] Normally the modifications will help anyone to run the machine. In Pat K---'s case, he was one of our most severely handicapped people. If we could fix the tube beader so that he could run it, then probably any of our other people could, too."

In order to design the modifications to the tube beader, Leonard had to know how the machine worked now--when run by an able-bodied operator--and also what the capabilities of the new operator, Pat K., were.

[1] Handicapped individual.

A Parker Power Flarer is shown in Exhibit B-1 and further described in Exhibit B-2. Leonard was able to observe the operation of the machine, as well as run it himself. He said, "Somebody had already added a strap, which bolted to the beader to help hold the tube in the right place. There was also a hopper for the tubes, which had been built at CIC.[2] The operator took a tube from the hopper and placed it on top of the strap.[3] This helped him get it in the right position. He held the tube against the strap with his left hand and closed the die with a lever using his right hand.[4] Once the die was closed, he could let go of the tube, since it was trapped in the die. Then he pulled the second lever.[5] This lever operates a mechanism inside the head of the machine for forming the bead. Basically, a small wheel[6] which can slip inside the tube is driven in an eccentric path by the motor. As it goes around, it is forced outwards, deforming the tube between the wheel and the die."

"This went on as long as he held the second lever," Leonard continued. "He used his judgement on this. The time depended in part on how well the machine was adjusted. It had some pretty badly worn parts which we've had to replace to get good, consistent beading."

"Then, after letting go of the second lever--which allows the beading wheel to retract--the operator removed the tube and tossed it in a tub. Then

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[2] A photograph of the hopper appears in Exhibit B-3.

[3] The strap bolted to the lower vise jaw (Exhibit B-1) and extended out to support the tube from below.

[4] The female die, Exhibits B-1 and B-2, is split. The two halves are carried in the vise jaws. The hand lever for the vise, Exhibit B-1, opens the die so the tube can be inserted; when closed, it clamps the tube in place.

[5] Hand Lever for Beading Head, Exhibit B-1.

[6] Beaders, Fig. K in Exhibit B-2. The beaders will be called beading wheels from here on to avoid confusion with the entire machine.

he started the whole process over again."

"What we had to do," Leonard said, "was to figure out some way that Pat could run this machine."

Pat K. was 26 years old. He had a relatively severe form of cerebral palsy and was confined to a wheelchair. Although he had never held a job, Pat had been in the CIC training program for a year and a half.

"Management wanted to find a job for Pat, and picked the tube beader," Leonard recalled. "There is more to something like this than just the engineering problem--adapting the machine to the client--however. It's a big adjustment for the handicapped, who may never have worked, to get used to an 8-hour day--the routine, the pacing. That's one of the functions of the training program. We're never sure if a client really has the motivation to work until they have a chance to try."

While it was easy for Leonard to watch the tube beader in use, it is not so simple to determine the capabilities of a potential handicapped operator such as Pat K. Leonard said, "I was able to work with Pat in the training area, but we also have a test called the Available Motions Inventory which we use to measure the capabilities of our clients. This gives us quantitative data on forces, ranges of movement, and so on."

Instruction B

The Available Motions Inventory had been developed over a period of several years by the REC staff. While you will not be able to duplicate their results, for this instruction you should make a list of the types of abilities which should be measured. Keep in mind that the objective of the test is to get data which can be used in placing the testee in a manufacturing job. Thus,

as noted above by Leonard Anderson, "forces, ranges of movement, and so on" are desired. It is now your job to consider what <u>specifically</u> should be measured, and how.

If you need help in following this instruction you might look in the library for books or articles on such topics as human factors, human engineering, or human factors engineering. These terms all pertain to the same general subject: the performance characteristics--physical, perceptual, mental--of people functioning in conjunction with man-made systems. The system, for example, might be an automobile, and the human characteristics such things as: height, as related to seat travel; vision, as related to headlight brightness; strength, as related to brake pedal force or steering wheel effort; reach, as related to the placement of the knobs on the radio. Obviously there is a wide range of human characteristics, so that statistical sampling is usually needed to gather useful information. And, while the examples above are commonplace, many more specialized areas of human factors engineering involve exotic military or aerospace applications. For example, the design of the life support systems for a space capsule involves many areas of human factors engineering. These may include psychological problems associated with confinement in the peculiar environment of the capsule, as well as physical protection during the high g-forces of lift-off.

The particular subdivision of human factors engineering with which Leonard Anderson and his colleagues at the REC and at CIC are typically concerned is often called man-machine engineering. This subdivision deals with the interactions of human operators and the equipment they use--whether it be a kitchen stove or a jumbo-jet. These interactions may require knowledge of the perceptual, as well as physical, abilities of the operator--e.g., how should information on the altitude of an airplane be presented to the pilot so that he or

she is least likely to misinterpret it? Note that probabilities are again inherently involved. Most past human factors engineering studies, as you might suppose of a relatively new field,[7] are directed towards the able-bodied--this despite the fact that 23 million people in the U.S. suffer from some type of physical handicap.

At some point in the discussion above, you may have thought that human factors engineering would seem to require little more than common sense. Unfortunately, experience shows that this is not really true. There are many well-documented cases where common sense has been wrong. You find some of these mentioned in a good, brief introductory book by Alphonse Chapanis entitled Man-Machine Engineering (Wadsworth Publishing Company, 1966, 134 pages).

At this point you should proceed to:

1. List the types of tests you think should be included in the Available Motions Inventory for determining the capabilities of the handicapped. Be specific.
2. Make a list of the particular kinds of abilities which you would like to know about for Pat K., the intended operator of the tube beader.
3. Reconsider, if it seems to you advisable, the decision to retain the Parker Power Flarer and adapt it to a handicapped operator. Do you think this will be hard to do? Why?

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[7] Human factors engineering received major impetus from studies of "pilot-error" accidents in military aircraft during the period of World War II. Many of these actually turned out to be designer-error accidents.

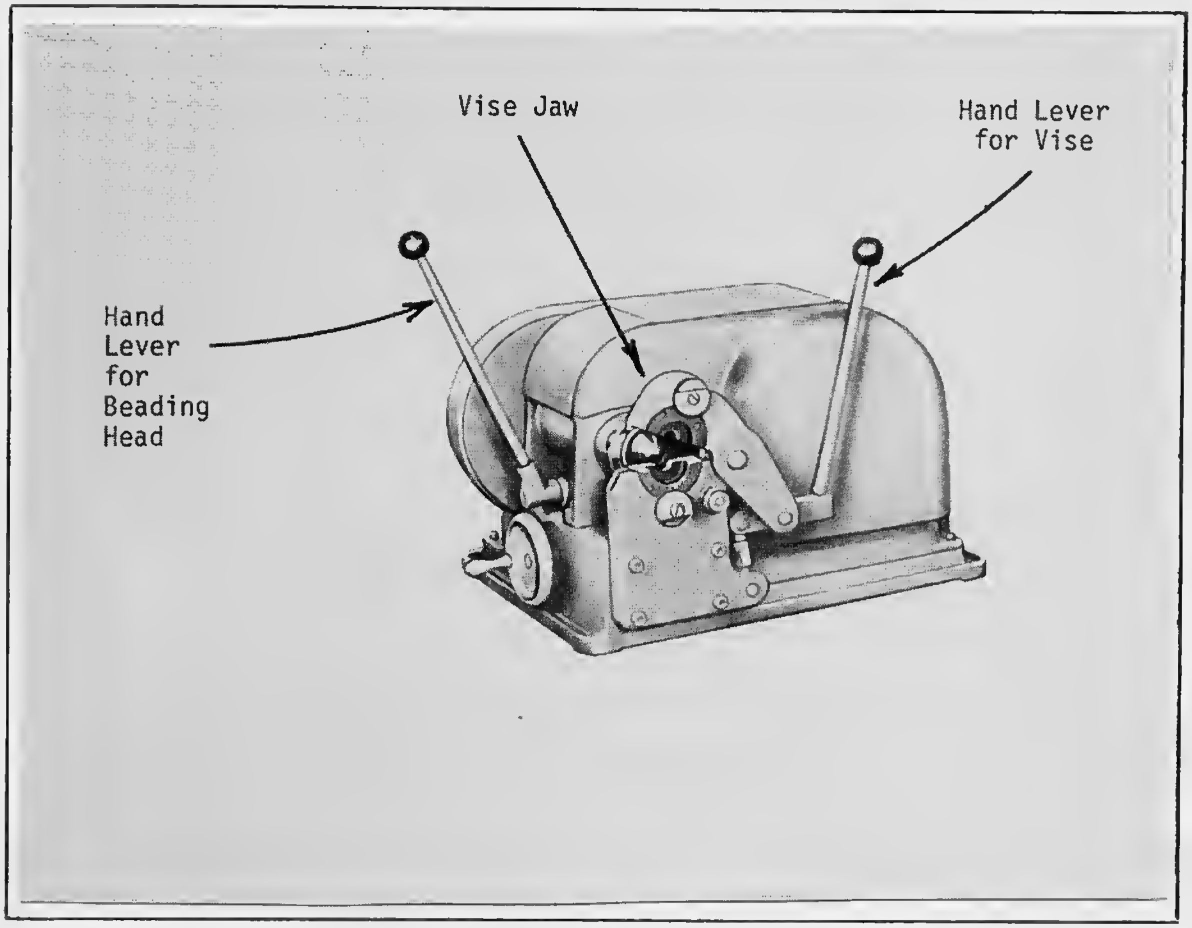


Exhibit B-1. Catalog Picture of Parker Power Tube Flarer (Notes Added by Casewriter).

Exhibit B-2. Excerpts from Parker Bulletin 4392-B20 on Tube Flarer. ECL 250B

Fig. H. Accessories for Beading

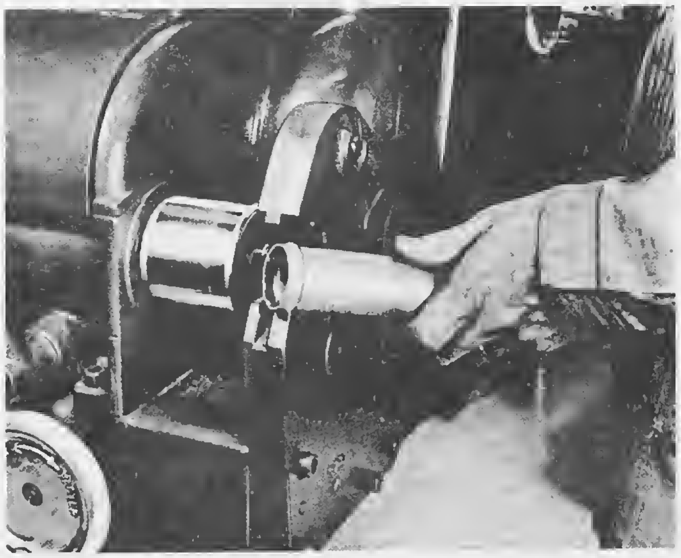


Fig. J. Beading Head in Operating Position

BEADING

Fig. K illustrates beading head for all tubing sizes from 4 through 24. Beading head screws onto spindle. Beaders snap into opening in head. In all sizes excepting 6 through 12 the tang on end of beader shank must be locked in place before beading.

End of tube should be flush with face of beading dies. Adjust travel stop nuts (arrow 9 and 10, Fig. C) to provide proper beading depth.

The beading tool runs concentric with the spindle until the head is advanced by means of the hand lever and brought to bear against the face of the dies. Further pressure initiates a cam action within the beading head and forces the tool outward pressing the tube wall into the beading die from cavity. Beading tool shank must be inserted full depth in the head in order to align correctly with the bead forming cavity in the die.

LUBRICATION

When machine is in steady operation, apply light spindle oil once a day or as needed in cavity below spindle stop adjusting screw to lubricate spindle sleeve.

Lubricate key slots on back of spindle with two or three drops of oil daily or as needed.

Variable speed pulley has grease fitting accessible through slot in back side of housing. Fill with good grade of grease once a month or as needed. Motor requires oiling occasionally.

Bearings are lubricated at factory for long, trouble-free service.

Oil any other moving surfaces — lever shaft, vise hinge pin, etc. — as needed.

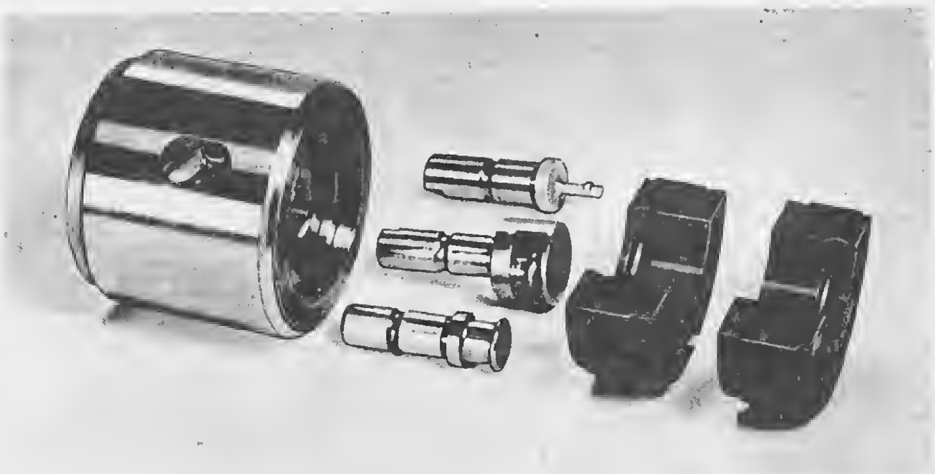


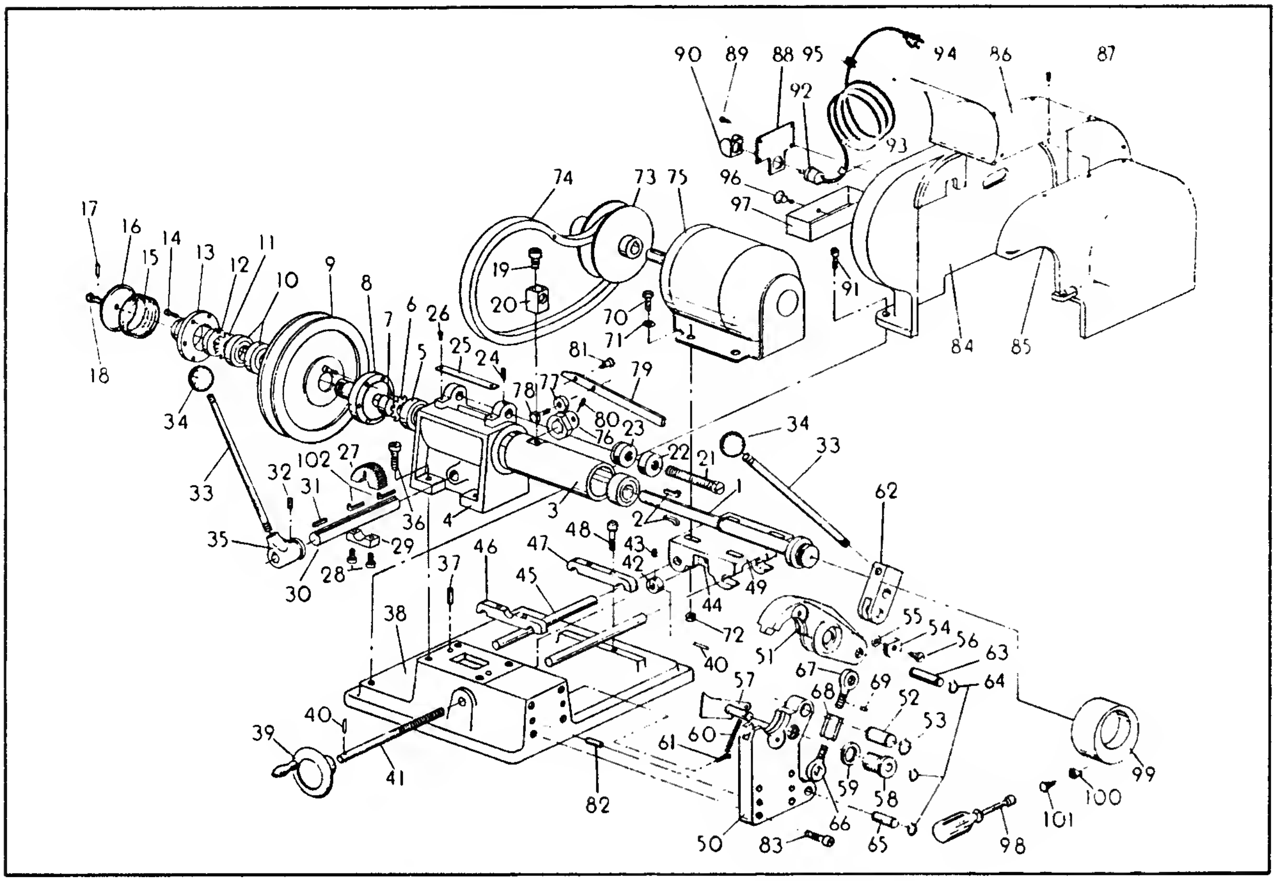
Fig. K.

Beading Head
Part No. 550557

Beaders
(specify tube O.D.)

Beading Dies
(specify tube O.D.)

PART LIST 232B



INDEX NO.	PART NAME	PART NO.	REQ.
1	Spindla	520603	1
2.	Key (Bent)	540666	2
3.	Sleeve (Spindle)	520600	1
4.	Housing (Spindle)	520599	1
5.	Bearing (Spindle)	520606	2
6.	Lockwasher (Spindle Bearing)	520607	1
7.	Collar (Spindle Bearing)	520608	1
8.	Pulley Mount	520612	1
9.	Pulley (Driven)	520617	1
10.	Bearing (Pulley)	520613	2
11.	Lockwasher (Pulley Baaring)	520614	1
12.	Collar (Pulley Bearing)	520615	1
13.	Spindle Dog	520616	1
14.	Cap Screw (10-32 x 3/8 Hollow Hax)	10 x 21	12
15.	Spring (Spindle Return)	540660	1
16.	Plate (Spindle Return Spring)	540661	1
17.	Roll Pin (1/8 Dia. x 7/8)	99 x 45	1
18.	Screw (5/16-18 x 3/4 Flat Haad)	3 x 309	1
19.	Cap Scraw (1/2-13 x 1/2)	10 x 287	1
20.	Traval Stop	520609	1
21	Screw (Travel Adjusting)	520610	1
22.	Nut (Travel Adjusting)	520611	1
23.	Locknut (Traval Adjusting)	540662	1
24.	Set Screw (1/4-20 x 3/8)	26 x 26	1
25.	Scale	520676	1
26.	Scraw (10-32 x 3/8 Round Haad)	4 x 104	2
27.	Gaar	540663	1
28.	Cap Scraw (1/4-20 x 3/4 Hollow Hax)	10 x 223	2
29.	Clamp (Gear)	540664	1
30.	Gaar Shaft	520622	1
31.	Kay (3/16 x 1)	22 x 10	1
32.	Sat Screw (5/16-18 x 3/8)	26 x 355	1
33.	Handla Rod	520624	2
34.	Ball (Handle)	520625	2
35	Bracket (Handle)	520623	1
36.	Cap Screw (3/8-16 x 1 1/4 Hollow Hex)	10 x 256	4
37.	Dowel Pin (5/16 x 1)	23 x 174	2
38.	Basa	520598	1
39.	Hand Wheel	520648	1
40.	Roll Pin (1/8 x 1")	99 x 47	2
41.	Screw (Speed Adjusting)	520651	1
42	Lock Collar (Adjusting Screw)	520652	1
43.	Set Screw (5/16-18 x 1/4)	26 x 14	1
44.	Square Nut (5/8-18)	16 x 12	1
45.	Slide Rod	520654	2
46	Clamp (Slide Rod, Front)	520655	1
47.	Clamp (Slide Rod, Rear)	540665	1
48.	Cap Screw (5/16-18 x 1 1/4 Hollow Hex)	10 x 241	4
49.	Motor Mount	520653	1
50.	Vise Jaw (Stationary)	540506	1
51.	Vise Jaw (Movable)	540507	1
52.	Pin (Movable Jaw)	540687	1
53.	Snap Ring (Truarc 5100-75)	56 x 212	2
54.	Lock Ring	520628	2
55.	Spring Washar	520629	2
56.	Shoulder Screw	520630	2
57.	Finger (Stop)	540668	1
58.	Sleeve (Finger Adjusting)	520635	1
59.	Lock Collar (Fingar Adjusting)	590602	1
60.	Spring (Stop Fingar)	540669	1
61.	Cap Screw (8-32 x 1/4 Round Head)	4 x 260	1
62.	Arm (Vise, Operating)	540513	1
63.	Pin	540516	1
64.	Snap Ring (Truarc 5100-50)	56 x 207	7
65.	Pin	540514	2
66.	Screw Eye (Left Hand)	540517	1
67.	Scraw Eya (Right Hand)	540518	1
68.	Nut (Vise, Adjusting)	540519	1
69	Thread Lock	540520	1
70	Cap Screw (5/16-18 x 1 Hax Head)	12 x 240	4
71.	Washer	34 x 11	4
72.	Nut (5/16-18)	17 x 102	4
73.	Pulley (Motor)	520657	1
74.	Belt	520658	1
75.	Motor (110 V, 1/2 H P.)	520656	1
76	Cam (Lever, Stop Finger)	540690	1
77	Roller (Lever. Stop Finger)	540691	1
78	Shaft (Roller)	540692	1
79	Lever (Stop Finger)	540693	1
80	Set Screw (1/4-20 x 1/4)	26 x 336	1
81.	Shoulder Screw (1/4 Dia. x 5/8)	540710	1
82	Dowel Pin (5/16 x 1 1/2)	23 x 178	2
83	Cap Screw (3/8-16 x 1 3/4 Hollow Hex)	10 x 258	4
84.	Housing (Belt End)	520663	1
85	Housing (Vise End)	520664	1
86.	Cover Assembly (Hinged Lid)	520666	1
87.	Screw (8-32 x 1/2 Round Head)	4 x 264	10
88.	Name Plata	520659	1
89	Screw (8-32 x 1/4 Round Head)	4 x 260	6
90.	Guard (Switch)	611077	1
91.	Cap Screw (5/16-18 x 3/4 Hollow Hex)	10 x 238	4
92.	Switch	520660	1
93.	Cord Clip	520670	3
94.	Cord Assembly	520671	1
95.	Grommet	520674	1
96.	Drawer Pull and Scraw	520662	1
97	Drawer	520661	1
98.	Wrench (Spintite 3412 3/8 Hex)	540708	1
99.	Chuck	520604	1
100.	Lock Collar	520605	1
101.	Differential Screw	520675	1
102.	Key (Bent)	540666	2

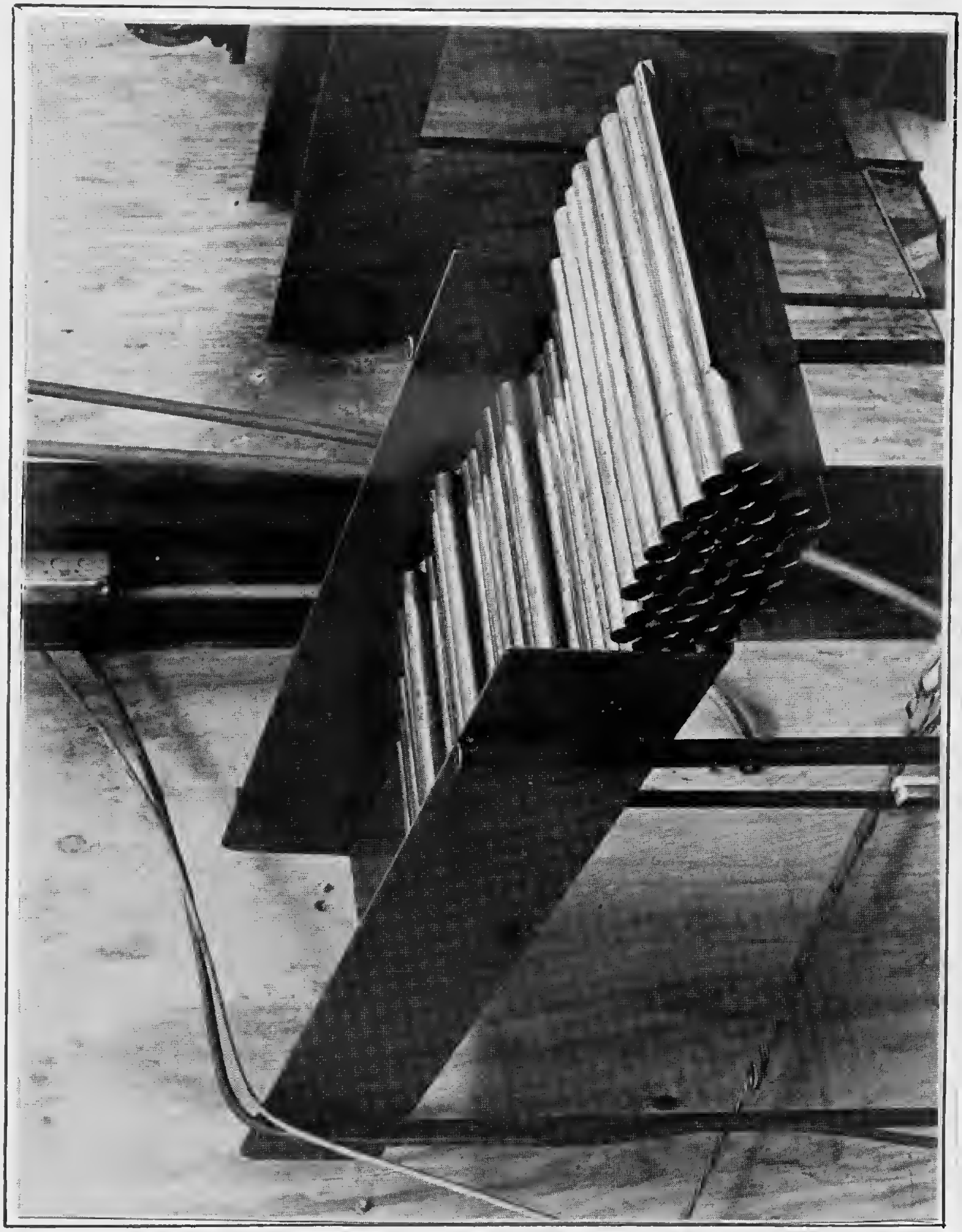


Exhibit B-3. Tube Hopper Used with Beading Machine.

CENTER INDUSTRIES CORPORATION (C)

Photographs of some of the equipment used for the Available Motions Inventory test are shown in Exhibit C-1, while Exhibit C-2 consists of excerpts from a manual describing the test equipment.

Leonard said, "The test includes measurements of the force the client can apply to levers and wheels, and also of grip strength.[1] There is a 'reach machine' for determining ranges of motion.[2] We also use tests of manual dexterity involving several types of dials and pushbuttons, plus a number of actual assembly tasks.[3] One of these, for instance, requires putting together nuts and bolts."

"The tests showed that Pat was fairly strong," Leonard continued. "However, he had poor coordination and muscular control. I was able to watch while he went through the test--which takes 3 or 4 hours--and it looked like he would only be able to perform fairly gross motions. One thing we found, which is pretty typical of people with cerebral palsy, is that Pat was much better at back-and-forth motions--at pushing and pulling--that at turning things. I probably learned most of what I needed to adapt the tube beader for Pat by working with him and watching him take the test, rather than from the actual quantitative data that we got."

Instruction C

At this state, assume you have adopted a definition of the problem much like Leonard Anderson's--that is, that the problem is to modify the existing

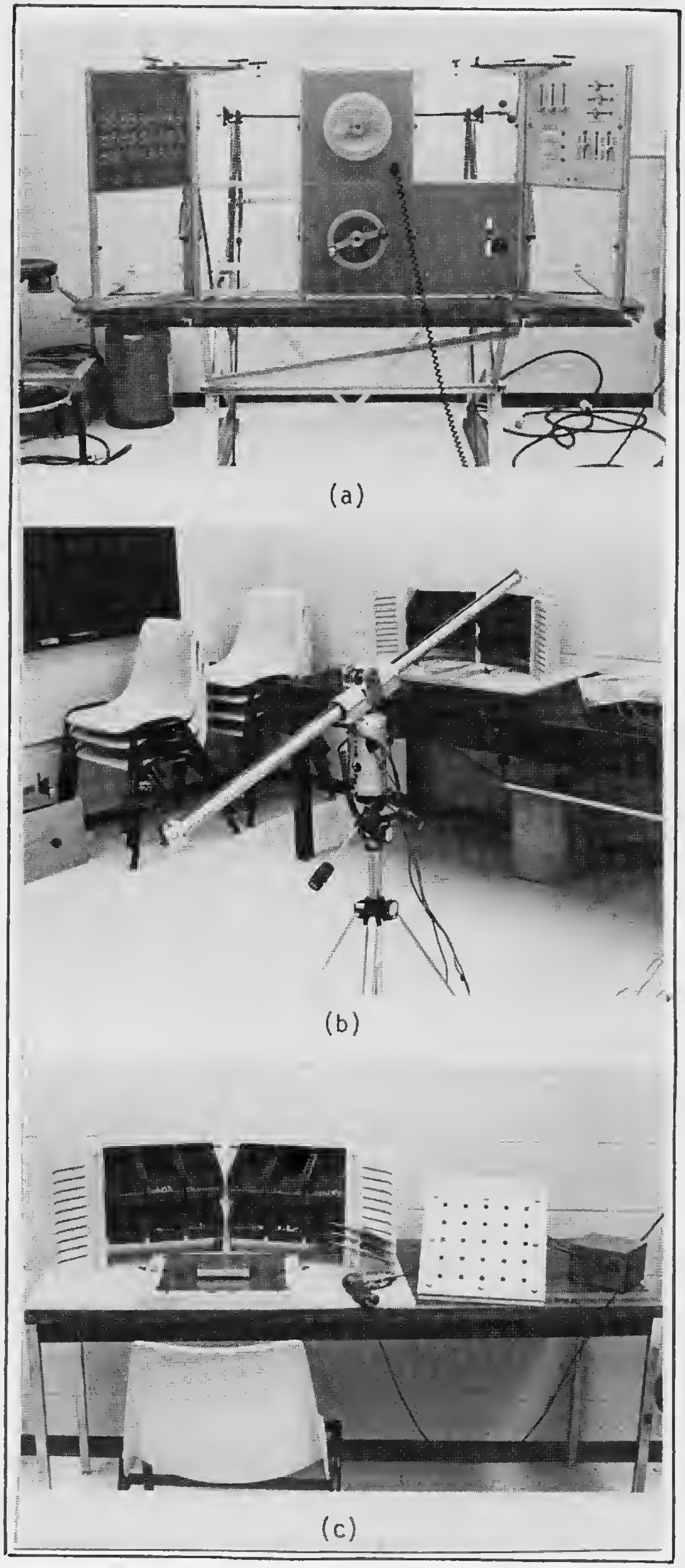
[1]Exhibit C-2a.

[2]Exhibit C-2b, foreground.

[3]Exhibit C-2c.

Parker Power Flarer by whatever "gadgets," attachments, or other modifications are necessary so that Pat K. can operate it at the required production rate. Now try to formulate the problem more precisely by answering the following questions:

1. Is there any more information that you need? If so, what? How will you get it?
2. Break down the tube beading operation into a sequence of discrete, fundamental steps (i.e., close vise jaw,...). Show these in a simple block diagram. At this point, concentrate on what the function is, not how it is to be performed.



(a)

(b)

(c)

Exhibit C-1. Equipment Used for Available Motions Inventory Test.

Exhibit C-2. Excerpts from Manual Describing Equipment Used for Available Motions Inventory Test.

The Available Motions Inventory for Evaluation of Physical Capability

It is fairly common practice for broad classifications established by medical diagnosis to be carried over into rehabilitation and job placement efforts. It is immediately obvious that these categories provide a qualitative description of the physical disability. These descriptions are useful in the medical and therapeutic treatment where there is a need to identify the pathology or disability for purposes of correction. In finding employment for the handicapped, however, a quantitative measure of a person's physical capabilities is essential. This rationale is the basis for the Available Motions Inventory as developed at Wichita State University by what is now designated as the Rehabilitation Engineering Center under the sponsorship of the Cerebral Palsy Research Foundation of Kansas.

The Available Motions Inventory samples a variety of physical tasks which are typically required in performing jobs in an industrial setting.

Limiting evaluation tasks to industrially related tasks is not meant to preclude expansion of the system to other job areas. Naturally, some overlap of tasks will occur so that many of the industrially related evaluation devices as presently developed will serve for other job areas as well.

Evaluation Hardware and Procedures

The devices which have been devised to evaluate a client's physical capabilities fall into two main categories: controls and assembly. The names given to the controls and assembly categories are not meant to imply that the information yielded by the devices in these categories applies exclusively to machine control or to assembly-job capabilities respectively. The information provided by either can have significance for both production and assembly types of industrial jobs.

1. Controls Hardware

A modular design was adopted for these devices. This concept allows for ready testing at various positions relative to the client.

* * *

A description of each module follows.

a. Maximum force indicators

The maximum force indicator has been designed to measure the maximum force that the client can apply in either a linear or a circular motion. The lever module is designed to measure force exerted linearly either up or down. The torque measuring module is to be actuated in either a clockwise or counterclockwise direction with a maximum applied force of 50 pounds. A handwheel and

a crank of 7 inches diameter can be interchanged on a shaft connected with the measurement system. The crank used to measure strength has two handles projecting from it. The peak detector records input from the module until it peaks out at which time a reading of the voltage proportional to the force applied can be read from a digital voltmeter. Upon resetting the device, a new measurement can be taken.

b. Dynamometers

A commercial pinch gauge has been purchased for the purpose of determining the client's pinch grasp; that is, grasp between the thumb and finger. A precision dial-indicator-arm shows the force applied by the client in a range from 0 to 30 pounds in one pound increments. To measure grasp a commercial grip gauge is also included in the evaluation hardware. Force is measured in pounds. These gauges complete the hardware used for measurements of strength in the Available Motions Inventory.

c. Rate and Settings

This module is designed to evaluate three functions; first, relative to rate, whether the client can rotate a handwheel or crank of diameter 7 inches with the resisting torque fixed within the range of his capabilities; second, also relative to rate, the maximum rate at which he is able to rotate the control; third; relative to settings, his ability to position the handwheel or crank at a given setting according to a graduated indicator dial.

Measurement of rate of rotation is accomplished by means of a revolution counter which records rotations completed in a specified length of time. The rate of actuation of the foot pedal is timed by the evaluator using a stop watch. Rate of completion of settings tasks is also timed by the evaluator.

The handwheel used for rate and settings is the same as that used with the strength module; however, the 7 inch crank used with rate and settings is the one having only one handle projecting from it. The scalloped handknob is a round knob approximately 2 1/2 inches in diameter with indentations on its outer rim. The compound rest has two small handles projecting from a 3 inch arm fastened at the center to the rotating shaft. The scalloped handknob has only one small projecting handle.

d. Switches

The module for rotary switches has ten knobs that are to be set to the position noted below each switch. This samples the client's ability to operate a continuously variable control in a circular direction. The rotary detent switches module looks much like the previously described module. These switches have a stop at each numbered setting similar to a television channel selector.

The slide switches module has three vertically and three horizontally variable switches. These model linear motion switches have recently appeared on commercially available sound equipment. They are operable by many handicapped persons who cannot actuate rotary switches.

The toggle switches module consists of 27 ON-ON switches that are to be actuated by moving them from the central "OFF" position to an up or down "ON" position as noted above each switch. Nine switches have no direction label and are to be left in the "OFF" position.

The pushbutton switches module consists of twenty-seven pushbuttons in three colors. They are to be actuated all of one color in one trial.

e. Assembly

All the assembly tasks but one are to be performed in conjunction with a specially designed work station.

* * *

In all, there are nine assembly tests. Each of these tests is described separately below.

1) Plates

This test involves aligning and placing a series of ten square aluminum plates on four bolts. Four holes have been drilled in each to accommodate the four bolts which are spaced such that each forms one corner of a square. Initially the plates are placed in the slotted rack on the work station.

2) Spacers

The station plate for this and for the four subsequent tests has ten bolts attached to it in two columns of five. For this test the client must take spacers from a parts bin one at a time and place it on each bolt.

* * *

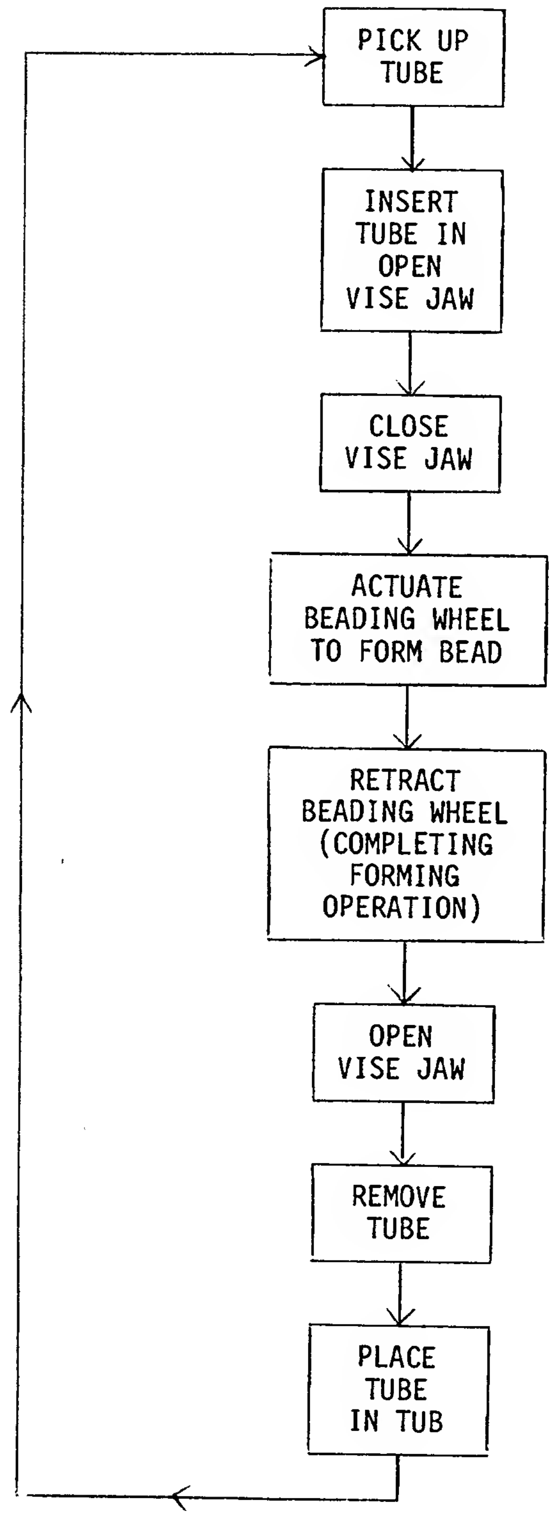
9) Drill

This test is concerned with the use of a pneumatic drill used to simulate both hand drilling and pneumatic screwdriving operations involving the fastening of nuts and screws. While the nuts and screws must generally be started by hand, an air driven tool is frequently used to tighten them. This is the only assembly test that does not make use of the work station. Instead, a separate testing station has been developed. This station consists of a small framework holding two parallel metal sensor plates. The plates are each one foot square and are held at a 45° angle to the horizontal. The upper plate has twenty-five holes drilled through it. The holes are arranged in five rows of five holes each 2 inches apart. A rubber grommet inserted into each hole serves a dual purpose. It acts as a spacer between the plates, thus electrically insulating them, and it also acts as a hole locator.

The task consists of placing the drill bit into each hole consecutively so that it comes in contact with the bottom plate. On the other hand, if during an attempt the client misses the hole, the bit will contact the upper plate. Both plates are connected to a counter box. Contact made by the drill bit through a grommet will register a "hit" or properly drilled hole, contact on the upper plate will record a "miss" or an improperly drilled hole.

CENTER INDUSTRIES CORPORATION (D)

Your block diagram should look something like that below.



Now we will examine these steps one at a time and consider how best they can be automated--or whether Pat can do them manually.

Instruction D

Consider the first box in the block diagram--PICK UP TUBE. In a more general sense, this might refer to any means of getting one of many tubes into the general vicinity of the vise jaws. Recall that at present the able-bodied operator picks up the tubes one at a time from the hopper which was shown in Exhibit B-3. Can Pat do this, or will he need assistance? If you cannot answer this question with the available information, how would you find out?

CENTER INDUSTRIES CORPORATION (E)

Leonard said, "Pat works from the same hopper that was used before. The tubes are 10 or 11 inches[1] long, which gives him a big target. He doesn't have much trouble picking them up; in fact, he'll often grab two or three at a time."

"My basic philosophy on something like this is 'If it works, it's OK,'" Leonard continued. "When we first had Pat try, we could see that he could use the old hopper. I don't think we should take all the work out of the job just because the operator has a handicap. After all, there's dignity in work. It's good for the client to have a feeling of accomplishment."

Leonard said, "I still feel that the hopper could use some refinement, though. Maybe this is something we'll look at in the future. However I wouldn't want to go too far. You could certainly build an automatic tube feeder--one that would drop a tube into position in the beader whenever Pat pressed a button. In fact, you see things like this all the time in mass production industries, where saving a few seconds may be important. But in our case we don't need this. And there's another thing you quickly find out. The first 80% of a job is easy to automate. But the last 20% is much harder, and it costs a lot more. Mostly we try to keep things simple."

Instruction E

Leonard said, "Although Pat could pick up a tube from the hopper, getting it in the right place in the die head is another story. Like

[1]The exact length is 273 mm (10 3/4 in.). The tubes have an outside diameter of 19 mm (3/4 in.) and a wall thickness of 0.76 mm (0.030 in.).

most people with cerebral palsy, Pat has poor muscle control, and would need some help in locating the tube. This is a typical problem in our machine modifications--I call it 'material handling'--that means getting a part in the right place at the right time. Much of my work involves designing attachments or fixtures for a machine to help a handicapped worker get a part in the right location."

Carry out the following tasks:

1. Design something to help Pat locate the tube within the vise jaws of the tube beader. Consider various alternatives, making a record of them in the form of sketches and notes.
2. Present your final proposed design in the form of either pictorial or orthographic sketches to approximately full scale. Specify the materials to be used in your design (i.e., steel, wood, aluminum . . .).
3. Present a plan for evaluating your design--i.e., answering the question "Will it work?" Would you be able to find out if Pat can use it satisfactorily without building and testing the complete design?
4. Imagine that your instructor has the role of your supervisor at Center Industries. Write him a <u>short</u> (maximum one typed page) memorandum explaining your progress to date and how you plan to proceed with the project.

CENTER INDUSTRIES CORPORATION (F)

Leonard thought of a simple holding fixture using a pair of cradles for helping Pat position the tube. A sketch he made of the cradles is reproduced in Exhibit F-1.

"This was the key part of the adaptation," he said. "But there was nothing scientific about it. I think the angles of the vee's in the cradles are 30 degrees--I just laid down a 30-60 triangle and drew them. I put a tool stop at the far end of the tube. This is something like the one on the steel strap fixture that had been on the machine before, only I made it bigger. The cradles help Pat with the gross location; then he can get the precise registration just by pressing the tube down in the U-shaped grooves at the bottom. I left plenty of space between the cradles for his hand."

"After sketching out the cradle, I made a model of it using a piece of 2 x 4 and some masonite. The model[1] was double-ended so Pat could try using it with either hand."

"I made the model myself. Then we C-clamped it to a bench and let Pat try it. I also made a wooden tube hopper for him to work from.[2] Right away we could see that the cradles worked pretty well and that Pat preferred to use his left hand. We timed him putting tubes in and taking them out for up to 2 hours to see if he'd be able to make the production rate. Since we weren't using the tube beader itself, I asked him to

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[1]A photograph of this model, set up for Pat K. to try it out, is shown in Exhibit F-2.

[2]Exhibit F-2.

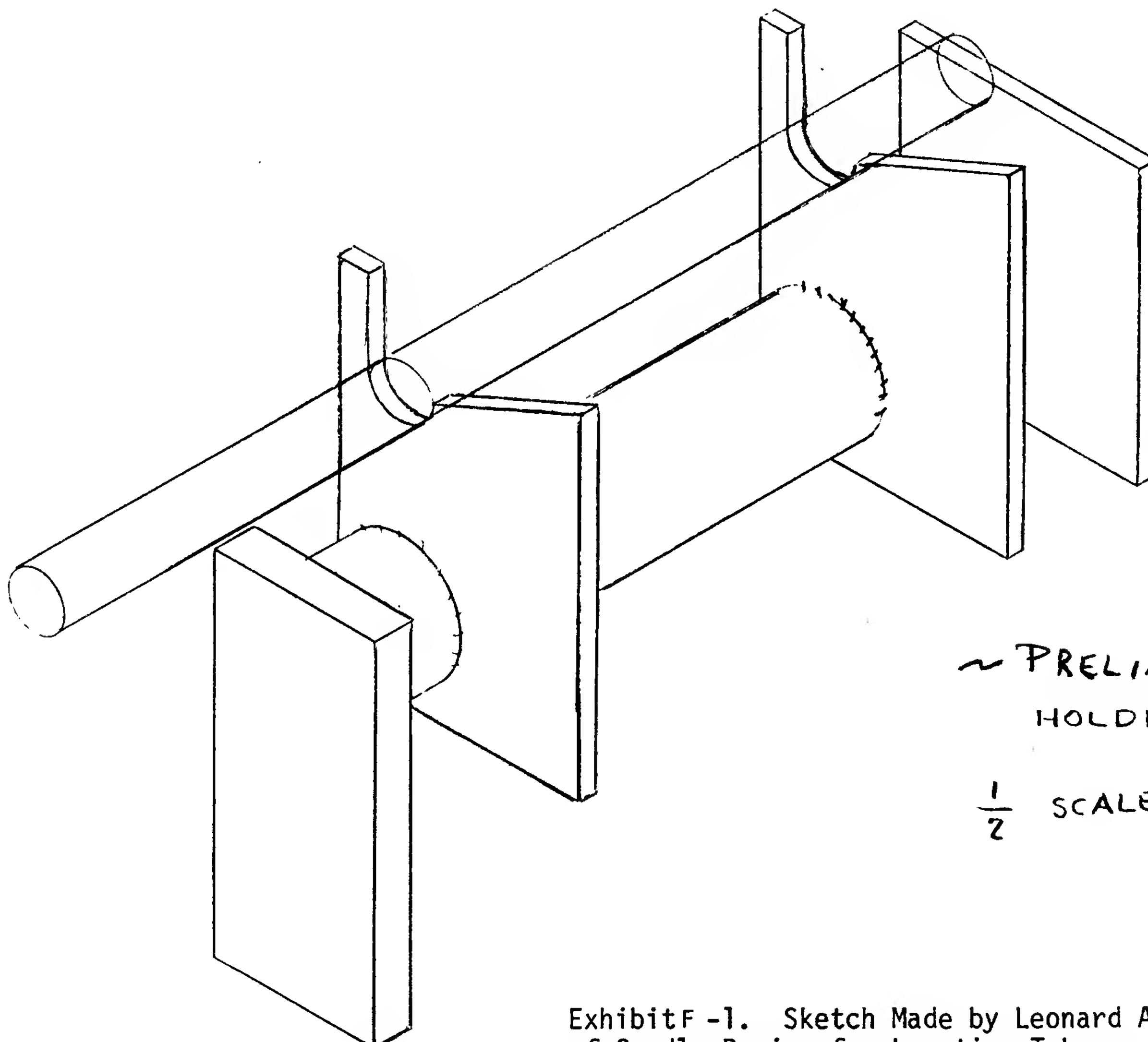
hold each tube in the cradles for a count of 5. This was because I estimated that the beading cycle itself would take 5 seconds."

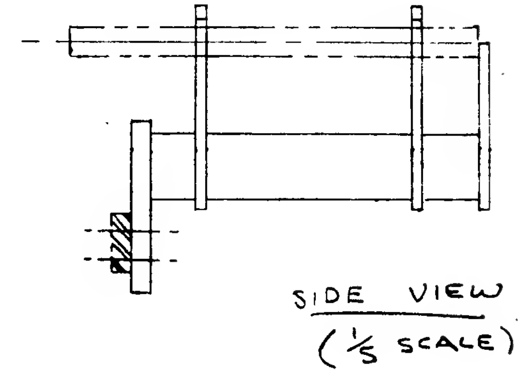
Instruction F

Leonard said, "I began to work on automating the rest of the operations as soon as we saw that the cradle concept was feasible. Pat would be sitting in his wheelchair facing the tube beader, and using his left hand to hold the tube in the cradles. Thus there was no way he could move the two levers on the machine. These were to his left, and we would have to find a way for him to operate the beader with his right hand."

Recall that the vise jaws were originally closed by a lever about half a meter long. This lever actuated a simple linkage, which can be seen in Exhibit B-1, to close the upper jaw (box 3 in block diagram, Section D).

1. List all the ways you can think of to:
   a) replace this lever by something Pat can operate with his right hand
   b) apply a force directly to the existing lever.
2. Choose the best alternative from the ideas you have accumulated in following Instructions 1(a) and 1(b) and explain why you think it is the best.





~ PRELIMINARY SKETCH ~.
HOLDING FIXTURE ~ TUBE BEADER

1/2 SCALE ISOMETRIC

L. Anderson
10-27-76

Exhibit F-1. Sketch Made by Leonard Anderson of Cradle Design for Locating Tubes.

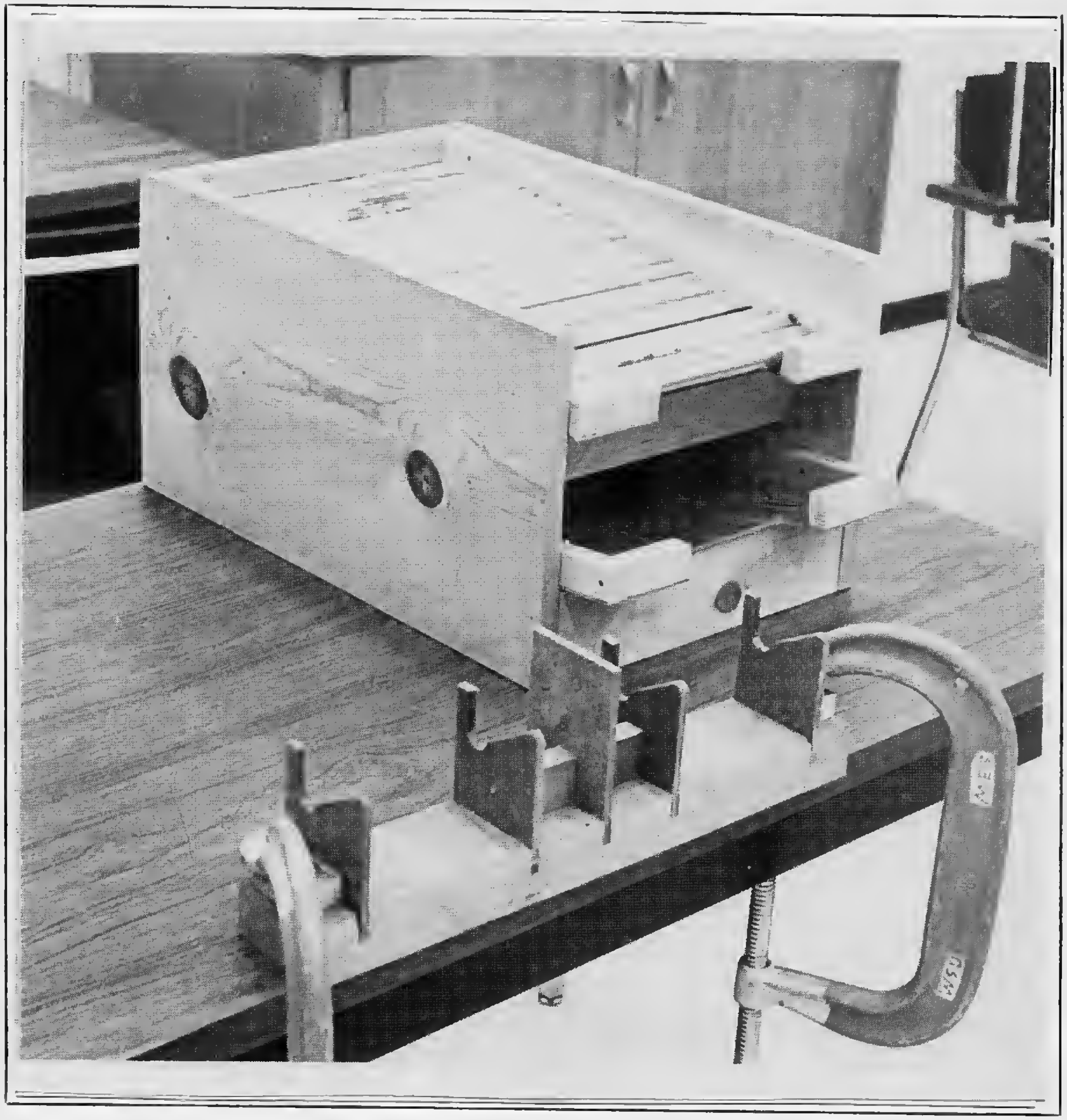


Exhibit F-2. Wooden Models of Cradle and Tube Hopper Made by Leonard Anderson.

CENTER INDUSTRIES CORPORATION (G)

There are many ways in which a force could be applied to close the vise jaw--either (1) directly; or (2), through a linkage; or (3), by pulling or pushing on the existing lever. These include:

-- a hydraulic cylinder (in which oil under pressure pushes on a piston)

-- an air cylinder (in which air pressure pushes on a piston)

-- an electric solenoid (which uses magnetic force)

These three methods would all give linear motion--a push or pull in a straight line--and could be controlled by a remote switch or valve which Pat could operate with his free right hand. It might also be possible to design a linkage from Pat's right hand to the die head so that he could apply the force directly. In addition, it would be possible to use an electric motor, air motor, or hydraulic motor.[1] The rotational motion of the output shaft of the motor could be directly coupled to the vise jaws in some way--for instance, through gears, a belt drive, or friction rollers. Alternatively, one of many mechanisms for converting rotational (straight line) motion could be used between the motor and the die head. Such mechanisms include: rack and pinion gears, a crank and rocker linkage, a scotch-yoke mechanism.[2] Most engineers would reject such ideas as unnecessarily complicated for this application.

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[1]Air motors or hydraulic motors use pressurized air or oil, respectively, to produce rotational motion. These typically have a rotor of some kind, driven by the pressurized fluid, rather than a translating piston as in an air cylinder or hydraulic cylinder.

[2]You can find out what these are in books on mechanisms or machine design. Such books also describe other mechanisms which perform similar functions.

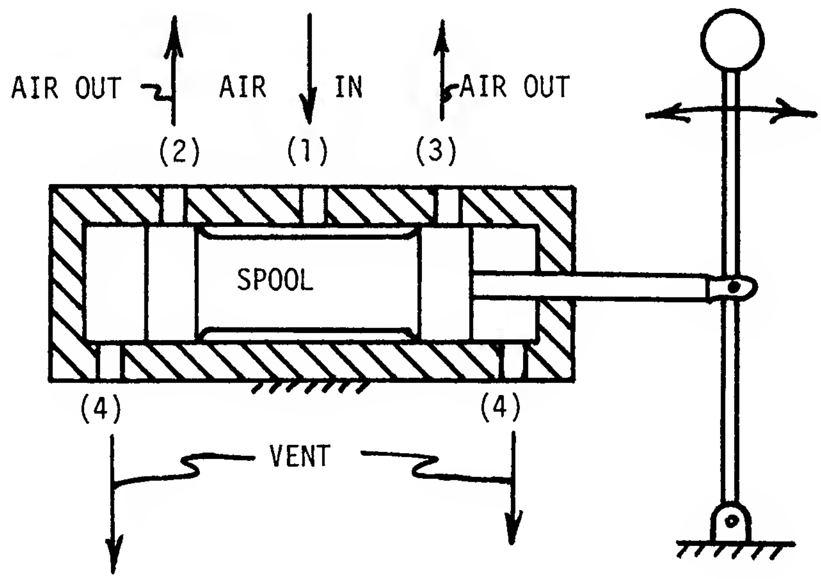
Leonard Anderson explained his own course of action as follows. "I had been thinking along the lines of air cylinders, and found a double-acting cylinder[3] of about the right size in a box full of surplus parts that I keep in my office. We set this up to open and close the jaws, with a 4-way valve controlling it. The hand lever was removed completely and the cylinder hooked up to the remaining linkage.[4] We put an extended handle on the 4-way valve

---

[3]A double-acting cylinder can apply a force in either of two directions, depending upon the side of the piston to which the high pressure air is admitted. Catalog information on air cylinders is included in Exhibit G-1.

[4]A photograph of the air cylinder installation is shown in Exhibit G-2. A 4-way valve is simply one with 4 passages connecting to the valve body:

4-Way Spool Valve Shown In Neutral Position



Air under pressure can be routed from the inlet passage (1), to either of the passages (2) or (3) depending upon whether the spool is moved to the left or right. If the compressed air is routed to passage (2), then passage (3) is automatically vented, and vice versa. For the tube beader, passages (2) and (3) would be connected to opposite sides of the piston of the air cylinder. The 4-way valve which Leonard used can be seen at the right in Exhibit G-3. This valve had a rotating valve body rather than the translating spool shown in the sketch above, but the principle of operation is the same.

and mounted it at the end of the cradle fixture so Pat can operate it with his right hand."[5]

When Pat pulls on the 4-way valve, compressed air at about 760 KPa (110 psi) is admitted to the air cylinder. The compressed air comes from a central compressor and is piped throughout the CIC plant; this is common practice in industry, and air cylinders, air motors, and air operated tools of various types are widely used where low force or torque levels are satisfactory. Of course, the compressed air also has other uses in a factory.

Leonard said, "Sometimes when we take visitors on a tour of the plant, they wonder why we make so much use of air cylinders. To me, it's so commonplace I don't even think about it--but air is right there in the plant, and it's cheap. Air cylinders are also cheap, because a little leakage is not serious. Hydraulics are much more expensive, and you only use them when high forces are needed."[6]

Instruction G

With the air cylinder installed on the vise jaw, the vise is snapped closed with considerable force. This is dangerous to anyone getting his hand in the way.

Answer the following questions:

---

[5]The finished cradle with the 4-way valve in place is shown in Exhibit G-3 (also see Exhibit G-2).

[6]Pneumatic or air systems typically operate at around 700 KPa (100 psi) and are thus suitable for forces in the vicinity of a thousand newtons (a few hundred pounds) with moderate piston areas. Hydraulic systems operate at several tens of MPa (several thousand psi) and develop much higher forces for a given piston area. High pressure air systems are seldom used because of the compressibility of air. When air or gases are compressed, large amounts of energy are stored. Accidental release of this energy--for instance, if a hose, tank or cylinder should burst--can be dangerous. In constrast, hydraulic oil is not very compressible and stores much less energy.

1. In a general sense, what kinds of safeguards should a machine of this type have?
2. Would these safeguards be different for an able-bodied operator than for a handicapped operated such as Pat K.?
3. Can you find specific regulations covering this situation in state or federal law (for instance regulations of the Occupational Safety and Health Administration (OSHA))?
4. Design a specific set of safeguards or safety devices for this machine. Illustrate them by sketches, using notes to explain their function.

Exhibit G-1. Page from Air Cylinder Catalog. ECL 250G

PNEUMATICS SHEFFER® HYDRAULICS

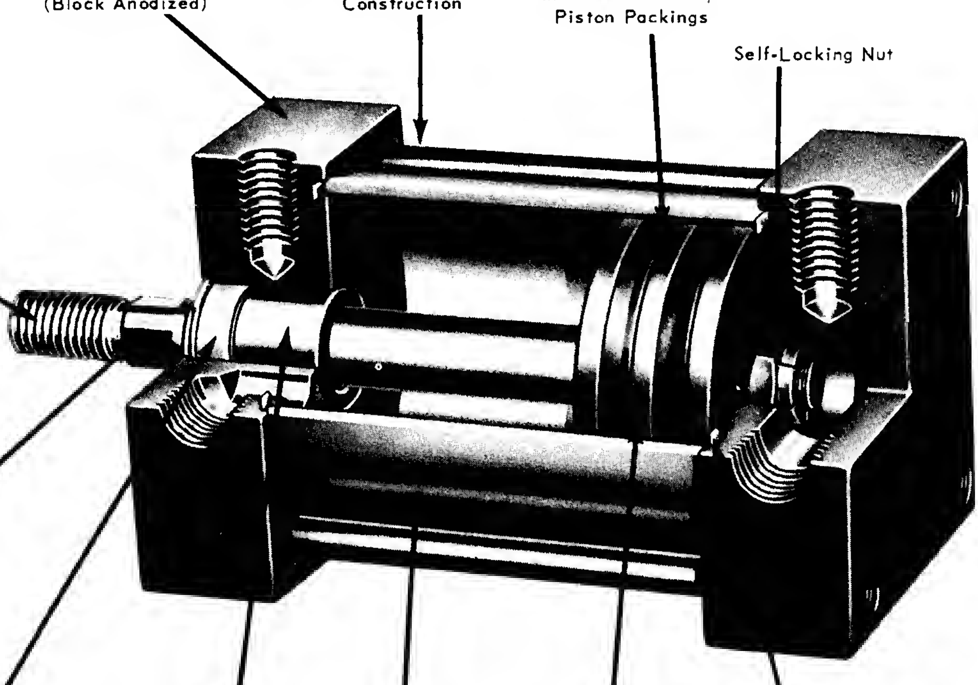
CLA SERIES

1 ½", 2" and 2 ½" BORE SIZES

150 PSI AIR

- COMPACT
- ECONOMICAL
- MOUNTING KITS AVAILABLE
- VERY SHORT OVERALL LENGTH
- IDEAL FOR TOOLING & AUTOMATION
- FAST DELIVERY

CONSTRUCTION FEATURES



PISTON RODS are af adequate size, of approximately 110,000 psi tensile steel. They are ground, polished and hard chrome plated for maximum wear and corrosion resistance. Faur (4) wrench flats are standard.

CYLINDER TUBES are high tensile aluminum alloy, hard anodized finish.

PISTONS are fine grain alloy cast iron secured with self-locking nut. Pistan faces are drilled and grooved and relieved far fast air flow to packings to eliminate blow-by and minimize breakaway.

BRONZE BUSHING, oil impregnated, for good lubrication and lang life.

CYLINDER ASSEMBLY is held tagether with high tensile steel tie rods. This is recognized by industry to be the best way ta pravide pre-stressed construction far rugged service.

HEADS are accurately machined from aluminum bar-stock and black anodized for protection and appearance.

PISTON PACKINGS are modified synthetic rubber "U-Cups". They are self-adjusting to pressure and wear. Their design allows simple replacement – no need to disassemble piston and rod. Lifetime lubrication is assured through "Moly-Filled" compound of seals.

ROD PACKING and **WIPER** combination is an extremely high abraisian resistant elastamer with a very long wear life. The rod seal is self-adjusting for pressure and wear. The wiper assures long life far the piston rod and bearing by both wiping and scraping to prevent foreign matter from entering the cylinder.

CONFINED GASKETS are used to seal the cylinder tubes at the heads to insure against leakage.

Exhibit G-2. Air Cylinder for Actuating Vise Jaw (A), Cradles for Locating Tube (B), and Microswitch (C).

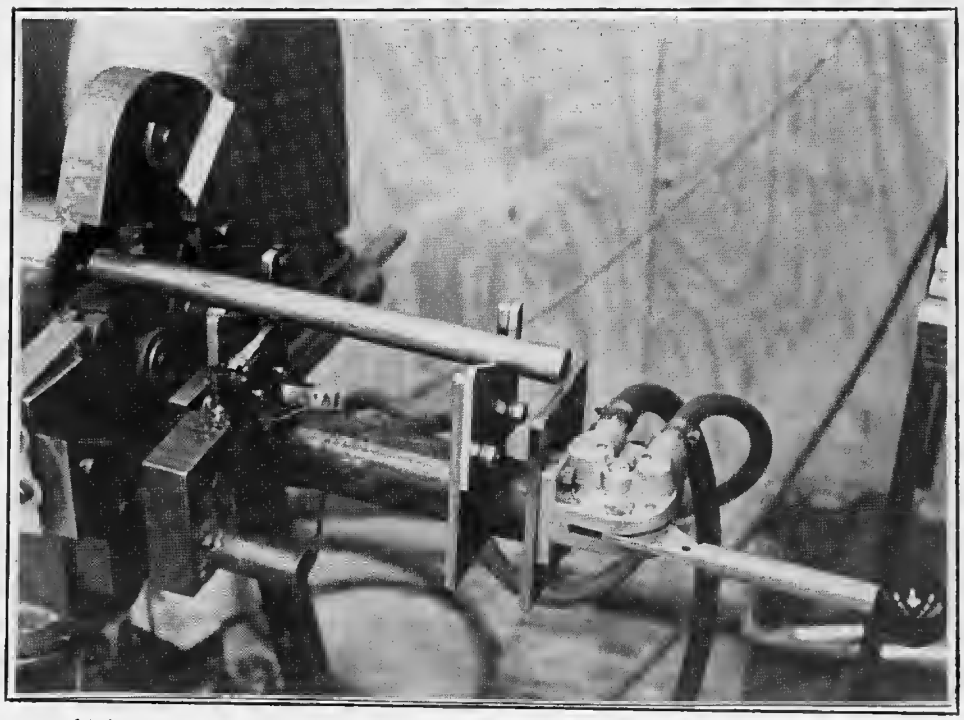


Exhibit G-3. Tube in Place in Cradles with Vise Jaw Open. Four-Way Valve to Right of Tube.

CENTER INDUSTRIES CORPORATION (H)

"I knew we'd have to make sure Pat's hands were out of the way of the die head," Leonard said. "This is standard practice and can be done either with guards or with dual switches of some sort. Many of our punch presses, for example, have two buttons. The operator has to press both at once--one with each hand--before the press will trip."

"For the tube beader, Pat's right hand would be on the air valve, so that was no problem. But his left hand, which he uses to hold the tube in the cradle, is not that far from the vise jaw. This can be a particular worry with a person like Pat, who has some spasticity and is liable to make erratic or inadvertent motions. But then anyone can have an accident, handicapped or not, and the principles are the same for any operator."

"To make sure Pat's left hand was out of the way," Leonard continued, "we mounted a microswitch[1] between the two cradles so that it would close when a tube was in position for beading. This also stops any inadvertent closing of the jaws. The spring loading of the switch is enough to pop the tube up out of position if Pat doesn't hold it down.[2] So he has to have his left hand on the tube before the air cylinder can work. The microswitch is in circuit with a solenoid valve[3] in the air line. Then, regardless

---

[1]Micro Switch is actually a trade name, but the term has come to refer to any small, spring-loaded snap action switch. Such switches are widely used as limit switches, for detection of parts or other objects, and for similar applications. A page from a Micro Switch catalog is reproduced in Exhibit H-1.

[2]This can be seen in Exhibits G-2 and G-3.

[3]Solenoid valves of this type operate electrically. A spring holds the valve body in either the open position (whence the valve is termed "normally open") or the closed position (a "normally closed" valve). A solenoid is an electromagnet with a moveable core. Application of a voltage creates a force to overcome the spring and either close or open the valve. Solenoid valves are simple and inexpensive; they are widely used in pneumatic and hydraulic systems for control purposes. A page from a solenoid valve catalog is reproduced in Exhibit H-2.

of the position of the 4-way valve, the vise jaw can't close until the switch is closed."

"A month or two after Pat started running the machine," Leonard continued, "we added a sheet metal guard after his elbow was bumped by one of the moving parts."

Leonard said, "I didn't have to check the OSHA regulations for this project because I knew what was needed. However there are other cases where we do have to get out the regulations and study them."

Instruction H

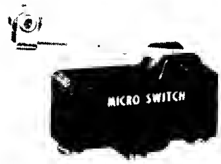
Recall the sequence of operations for the tube beader as diagrammed in Section D. After the vise is closed, the beader wheel is inserted into the tube and forced outwards to form the bead. In the original machine, this is controlled by a second hand lever (Exhibit B-1).

Answer the following questions:

1. Should this step be automated?
2. If so, how can this be accomplished? Think of as many ways as you can and describe them using sketches and/or notes. Specify your preferred design and explain why it is best.
3. How can you control the sequence of operations so that the beader wheel cannot enter the tube before the die head is closed?

MICRO SWITCH

TYPE "A" 20 AMPERE CAPACITY SWITCHES



ROLLER LEVER

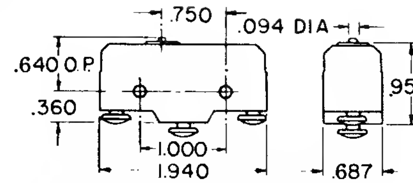
CIRCUITRY

Single-Pole Double-Throw (single-throw switches available)

High Inrush Capacity—75 Amps.
Lamp Load Rating
Accurate Repeatability
10 Million Operation Minimum Mechanical Life
Temperature Range— —65°F to +180°F
Screw or Solder Terminals
UL and CSA Listed
Momentary Contact

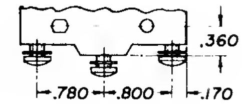
ELECTRICAL RATING

UL and CSA Listed:
20 amps, 125, 250 or 480 vac;
10 amps, 125 vac ("L" — a-c tungsten lamp load);
1 hp, 125 vac; 2 hp, 250 vac;
1/4 amp, 250 vdc; 1/2 amp, 125 vdc.

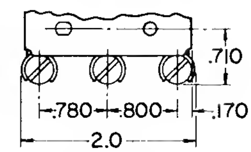


MOUNTING HOLES ACCEPT PINS OR SCREWS OF .139 DIA

TERMINALS



Screw/Cup **"A2"**. Bottom facing 6-32 NC x .218" screw terminals with cup-washers.



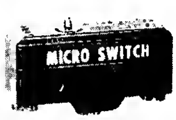
Screw/Lock **"T"**. Bottom facing 6-32 NC x .218" screw terminals with sems lockwashers.

Side Screw **"P4"**. Side facing 8-32 NC x .218" screw terminals with cupwashers.

Solder terminals. Use up to #14 wire.

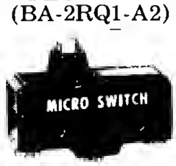
STRAIGHT LEVER (BA-2RV-A2)

FORMED LEVER (BA-2RV118)

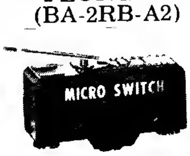


PIN PLUNGER (BA-2R-A2)

PANEL MOUNT PLUNGER (BA-2RQ1-A2)



OVERTRAVEL PLUNGER (BA-2RB-A2)



FLEXIBLE LEAF (BA-2RL-A2)

ORDER GUIDE

Mounting dimensions on page E-14.

	Description	Mtg. Fig.	O.F.	R.F.	P.T.	O.T.	D.T.	O.P.	F.P.	Terminal Variation	Order This Switch Listing
STRAIGHT LEVER	Low (2.5 oz.) O.F.		2.5	.5		.078	.109	.750	1.375	"A2"	BA-2RV-A2
	Lever can be cut	17	oz.	oz.		in.	in.	±.030	in.	"P4"	BA-2RV-P4
	or bent for adjustment		max.	min.		min.	max.	in.	max.	"T"	BA-2RVT
										Solder	BA-2RV
	Shaped lever allows		5	1	.310	.047	.055	.875			
	close timing	18	oz.	oz.	in.	in.	in.	±.030	—	Solder	BA-2RV118
	in cam operation.		max.	min.	max.	min.	max.	in.			
ROLLER LEVER	1.90" lever with		3.5	.5		.063	.035	1.188	1.656	"A2"	BA-2RV2-A2
	hardened steel	19	oz.	oz.		in.	in.	±.030	in.	"P4"	BA-2RV2-P4
	roller.		max.	min.		min.	max.	in.	max.	"T"	BA-2RV2T
										Solder	BA-2RV2
	1.05" lever with		6	1.5		.031	.047	1.172	1.422	"A2"	BA-2RV22-A2
	hardened steel	19	oz.	oz.		in.	in.	±.015	in.	"P4"	BA-2RV22-P4
	roller.		max.	min.		min.	max.	in.	max.	"T"	BA-2RV22T
										Solder	BA-2RV22
PIN PLUNGER	In-line motion.		14-	10	.050	.010	.002-	.625		"A2"	BA-2R-A2
	Accurately held	20	22	oz.	in.	in.	.0075	±.015	—	"P4"	BA-2R-P4
	operating		oz.	min.	max.	min.	in.	in.		"T"	BA-2RT
	characteristics.									Solder	BA-2R
PANEL MOUNT PLUNGER	For mechanical or		14-	10	.050	.219	.002-	.860		"A2"	BA-2RQ1-A2
	manual operation.	21	22	oz.	in.	in.	.0075	±.030	—	"P4"	BA-2RQ1-P4
	Panel adjustable		oz.	min.	max.	min.	in.	in.		"T"	BA-2RQ1T
	operating point.									Solder	BA-2RQ1
OVERTRAVEL PLUNGER	0.28" dia. plunger.		14-	10	.050	.093	.002-	1.030		"A2"	BA-2RB-A2
	Can be used with	22	22	oz.	in.	in.	.0075	±.020	—	"P4"	BA-2RB-P4
	20° rise cams.		oz.	min.	max.	min.	in.	in.		"T"	BA-2RBT
										Solder	BA-2RB
FLEXIBLE LEAF	1.78" straight		9	1		not	.065	.688	1.000	"A2"	BA-2RL-A2
	leaf. Overtravel	23	oz.	oz.		over	in.	±.030	in.	"P4"	BA-2RL-P4
	should be limited		max.	min.		.063	max.	in.	max.	"T"	BA-2RLT
	to 0.063".					in.				Solder	BA-2RL
	1.64" leaf with		9	1		not	.065	1.125	1.437	"A2"	BA-2RL2-A2
	0.375" dia. x 0.157"	23	oz.	oz.		over	in.	±.030	in.	"P4"	BA-2RL2-P4
	hardened steel		max.	min.		.063	max.	in.	max.	"T"	BA-2RL2T
	roller.					in.				Solder	BA-2RL2

Characteristics: O.F.—Operating Force; R.F.—Release Force; P.T.—Pretravel; O.T.—Overtravel; D.T.—Differential Travel; O.P.—Operating Position.

Exhibit H-1. Page from Micro-Switch Calalog.

Exhibit H-2. Page from Modernair Catalog. A Valve of the Type Marked "A" Was Used in Series with the Air Cylinder on the Vise Jaw.

MODERNAIR®
SOLENOID VALVES
MINIATURE SOLENOID VALVES
FOR AIR, OIL AND WATER SERVICE

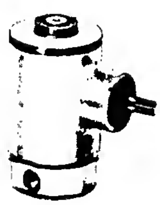

5433 33 01

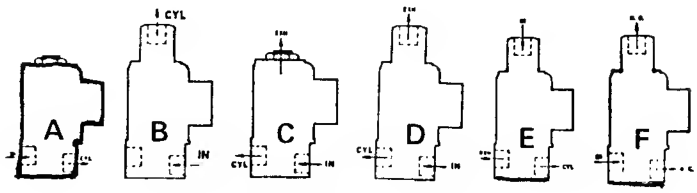
STANDARD

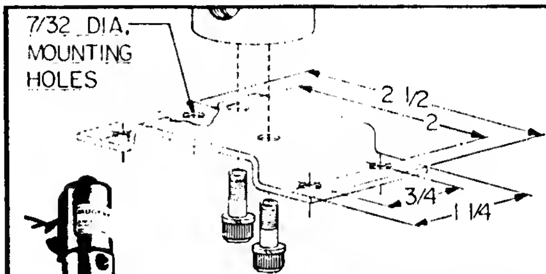

5430-33-01


5463-33-01

EXPLOSION PROOF


5460-33-01





9948 Optional Mounting Kit for all Series 54 Solenoid Valves.

Function	Valve Type	Model No.	Orifice Size NC Port	Orifice Size NO Port	Max. Oper. Pressure	C_V Factor	SCFM*	Wt.
A 2-Way, Normally Closed	Std. Std.	5423 5424	3/32 1/8	— —	150 100 AC 80 DC	.160 .215	5.7 7.7	12 oz.
	Exp. Pr. Exp. Pr.	5453 5454	3/32 1/8	— —	150 100 AC 80 DC	.160 .215	5.7 7.7	26 oz.
B 2-Way, Normally Open	Std.	5427	—	1/16	175	.087	3.1	12 oz.
	Exp. Pr.	5457	—	1/16	175	.087	3.1	26 oz.
C 3-Way, Normally Closed	Std.	5430	3/64	1/16	150	.053	1.9	12 oz.
	Exp. Pr.	5460	3/64	1/16	150	.053	1.9	26 oz.
D 3-Way, Normally Closed, with Piped Exhaust	Std.	5433	3/64	1/16	150	.053	1.9	12 oz.
	Exp. Pr.	5463	3/64	1/16	150	.053	1.9	26 oz.
E 3-Way, Normally Open	Std.	5435	3/64	3/64	150	.057	2	12 oz.
	Exp. Pr.	5465	3/64	3/64	150	.057	2	26 oz.
F 3-Way, Directional Control	Std.	5438	3/64	3/64	225	.053	1.9	12 oz.
	Exp. Pr.	5468	3/64	3/64	225	.053	1.9	26 oz.

*Flow capacity approximate.
(90 PSIG supply, 75 PSIG outlet)

MAXIMUM OPERATING SPEED
800 C.P.M.
RESPONSE TIME

AC VOLTAGE
8.4 milliseconds de-energizing
5.2 milliseconds energizing

DC VOLTAGE
9.4 milliseconds de-energizing
6.8 milliseconds energizing

HOW TO ORDER. Specify 4-digit model number above; then refer to table at right and add 2-digit coil number to indicate voltage. Add port size:

−01 = 1/8 N.P.T.F.; −02 = 1/4 N.P.T.F.

EXAMPLE: Model 5430-33-01, Series 54, 3-way normally closed, 60 cycle 115 volts, 1/8" Pipe Ports.

SOLENOID COIL OPTIONS

Coil No.	A.C. Voltage 60 Cy.	A.C. Voltage 50 Cy.	Inrush Amps	Hold. Amps	Lead Wire Color	Coil No.	D.C. Volt.	Hold. Amps	Lead Wire Color
30	6	6	2.5	1.7	White-Red	37	6	1.2	Green-Red
31	12	12	1.3	.85	White-Yellow	38	12	.60	Green-Yellow
32	24	24	.66	.43	White-White	39	24	.31	Green-Green
33	115	110	.14	.09	Black-White	40	115	.065	Green-Black
34	145	135	.11	.07	White-Green				
35	230	220	.07	.045	Yellow-Black				
36	460	430	.035	.022	Red-Black				
41	550	510	.029	.018	Black-Black				

SOLENOID SPECIFICATIONS

Coil rated for continuous duty at ±10% of rating. Maximum power consumption, 7 watts AC, 7.5 watts D.C. Furnished with 24" thermoplastic leads. Epoxy-molded Class A coils furnished as standard. Suitable for continuous energization at 25° C. (77° F.) maximum ambient temperature. Designed for 85° C. temperature rise above 25° or 110° C.(230° F.) total temperature.

CENTER INDUSTRIES CORPORATION (I)

Leonard said, "I found another air cylinder to use for the beader wheel. This turned out to be even simpler than closing the die. We just sawed the top part of the lever off and attached one end of the air cylinder to it.[1] This cylinder is controlled automatically. When the vise jaw closes, it trips a second microswitch.[2] Closing the switch causes a solenoid valve to open, admitting high pressure air to the cylinder. This takes care of the sequencing, but we still had to have some way to control the time for the beading operation. I wanted this to be variable. How long the beader wheel is held out against the tube--actually the number of revolutions--effects the height of the bead, so we wanted to be able to vary this. In the original machine, all these operations were manual, and the operator controlled the beading time directly. But here it had to be automatic, since Pat already had enough to do."

Instruction I

Think of as many ways as you can for providing a variable cycle time for the beading operation. The air cylinder for the beader wheel should be reversed automatically at the end of the predetermined time. Choose the best of your alternatives and describe with sketches, diagrams and notes how it would be implemented.

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[1]A photograph of this installation appears in Exhibit I-1.

[2]Visible in Exhibits G-2 and G-3.

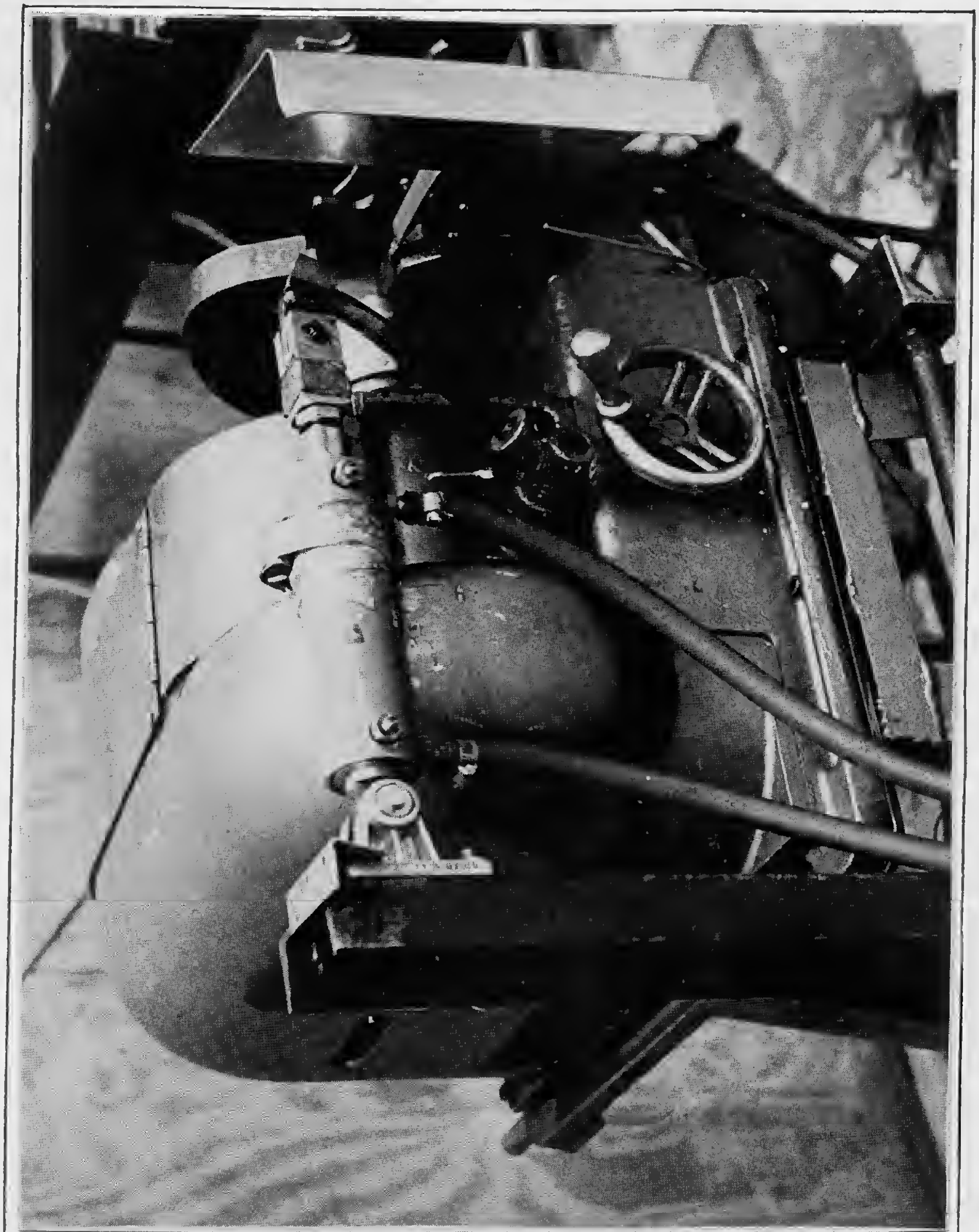

Exhibit I-1. Air Cylinder Attached to Lower Part of Original Hand Lever for Beading Head (see Exhibit B-1 for Original Configuration).

CENTER INDUSTRIES CORPORATION (J)

Leonard said, "I wrote a memo to Roy Norris, our Director of Technical Staff, describing what was needed for the sequencing and timing. Roy is an electrical engineer, so this was more down his alley. I gave him the logic requirements and he worked out the rest."

Leonard described Roy's solution to the sequencing problem as follows. "He used an adjustable timer that's turned on by the microswitch under the vise jaw.[1] When the pre-set time is up, the air cylinder on the beader wheel is reversed. This pulls the wheel back out of the tube. When Pat sees the lever move, he knows the beading is complete and he can release the 4-way valve. The vise jaw opens and he takes the tube out and tosses it in the tub."

Instruction J

Construct a diagram showing how the two air cylinders, the two microswitches, and the various valves, air lines and wiring should be interconnected. Your diagram should enable a technician or mechanic who does not know what the system is supposed to do to put it together properly.

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[1]This timer is shown in Exhibit J-1.

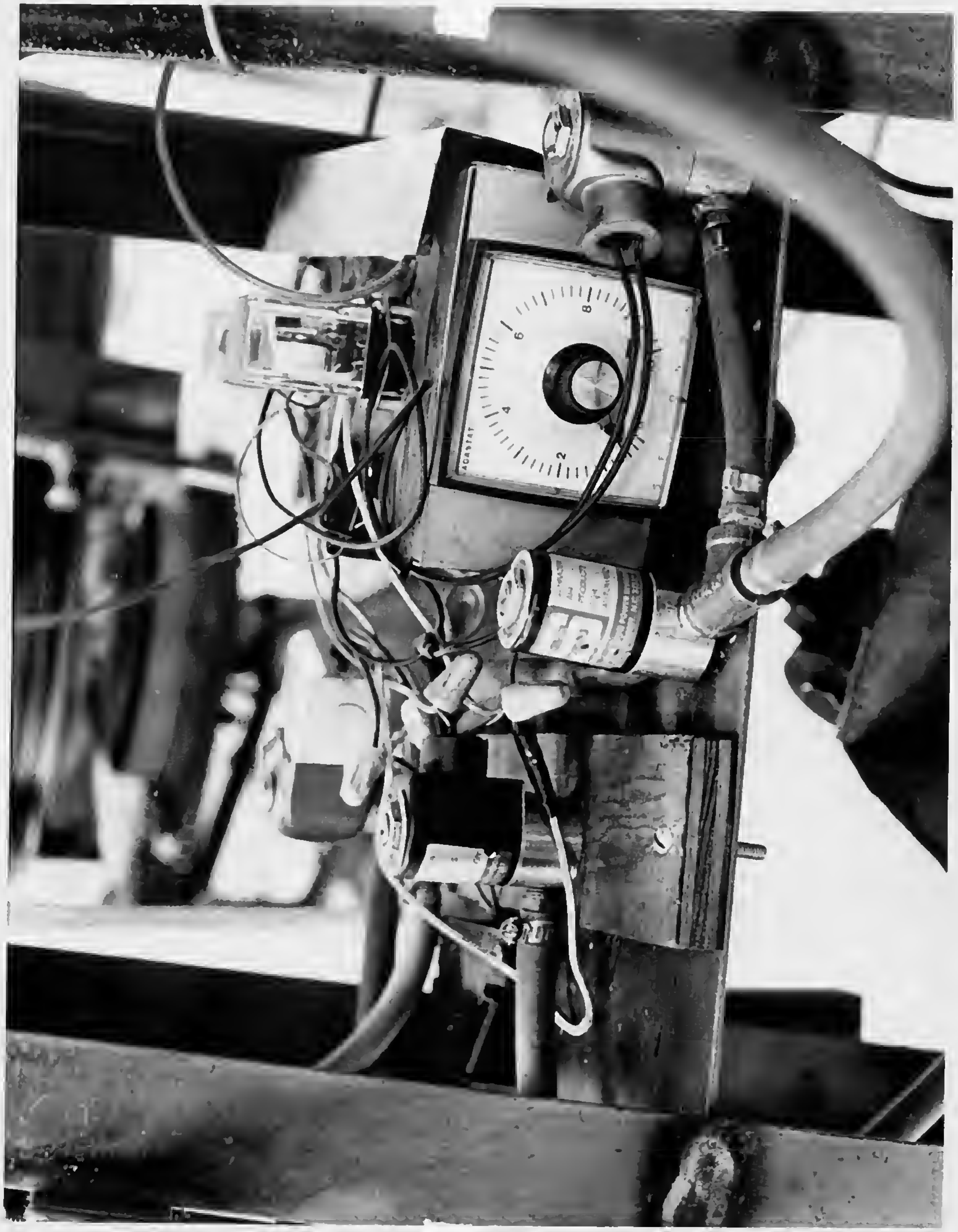


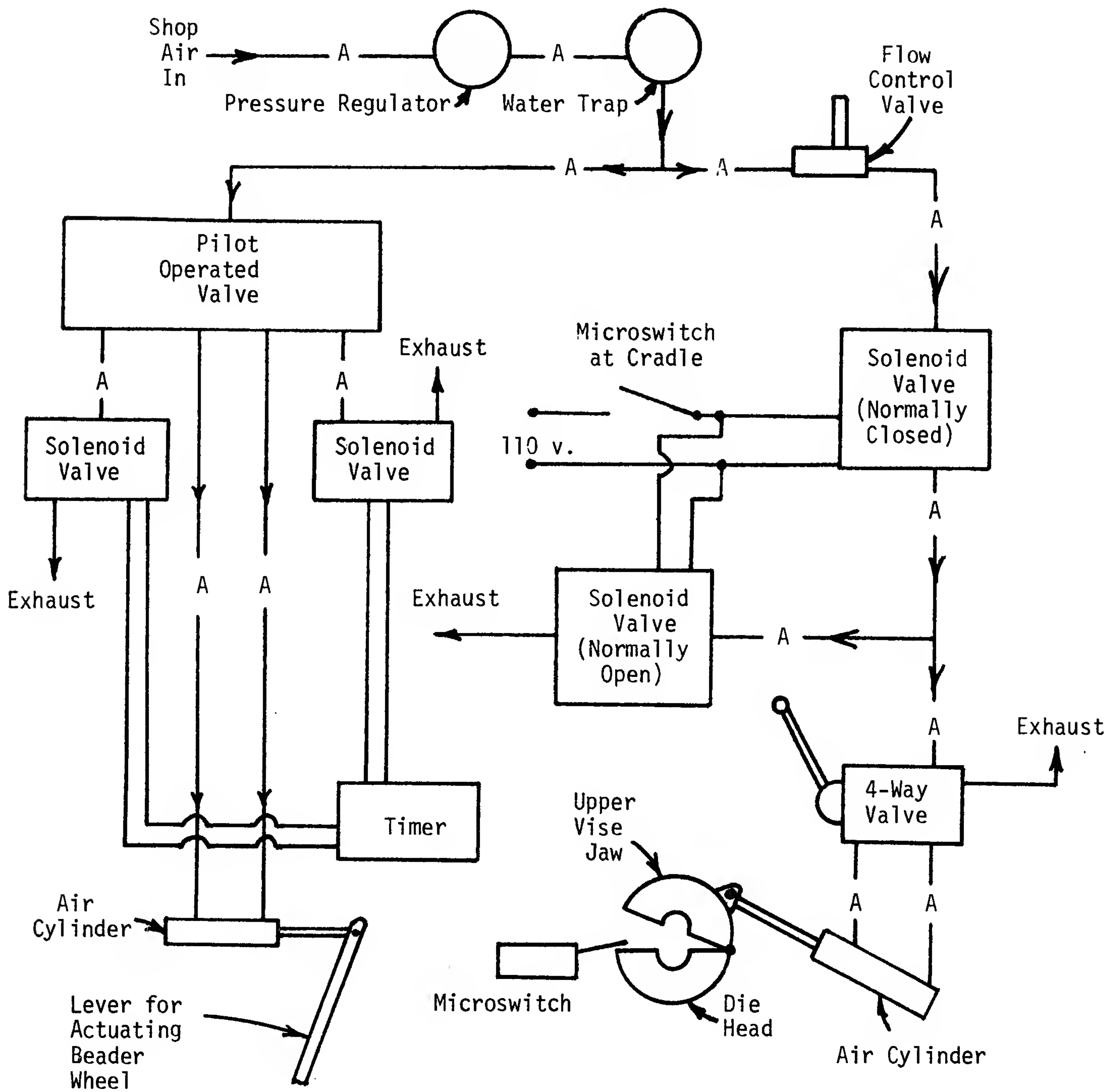
Exhibit J-1. Timer (with Dial on Front), Relays (on Top of Timer), and Various Solenoid Valves and Air Hoses, all Installed on Shelf below Tube Beader.

CENTER INDUSTRIES CORPORATION (K)

A circuit diagram for the combined air/electrical system is shown below.

———————— Electrical Wiring

——A———— Air Line



There are various simplified conventions for representing many of the components shown. While these are typically employed in more formal engineering drawings,[1] they have not been used above because our concern is with the logic of the system.

Leonard himself never made such a diagram, however. He explained that since he put the entire system together himself, there was no need for one. "We were in a rush to get this built," he said, "and there was no one here to help me at the time. I did all the work, including the welding and plumbing the air lines. Roy wired the electrical parts. Actually, I enjoy this kind of thing. I just assembled the system piece by piece, knowing how I wanted it to work. We only had to buy one solenoid valve; everything else we had around. After the system was operating, I added a flow control valve[2] to keep the air cylinder from slamming the vise jaw closed too hard and also an exhaust[3] on this cylinder to release the pressure. Without this exhaust, the cylinder and lines would store enough air to close the vise a second time. That's about the only thing that had to be changed after we put things together."

"The system is a little more complicated than it needs to be," Leonard pointed out. "That's because we used parts we already had. There is no need

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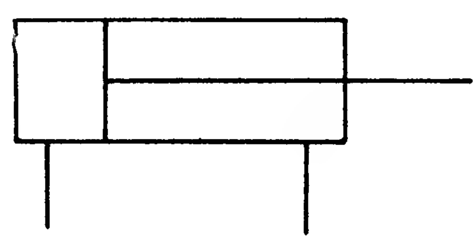
[1]For example, a double-acting cylinder is represented by

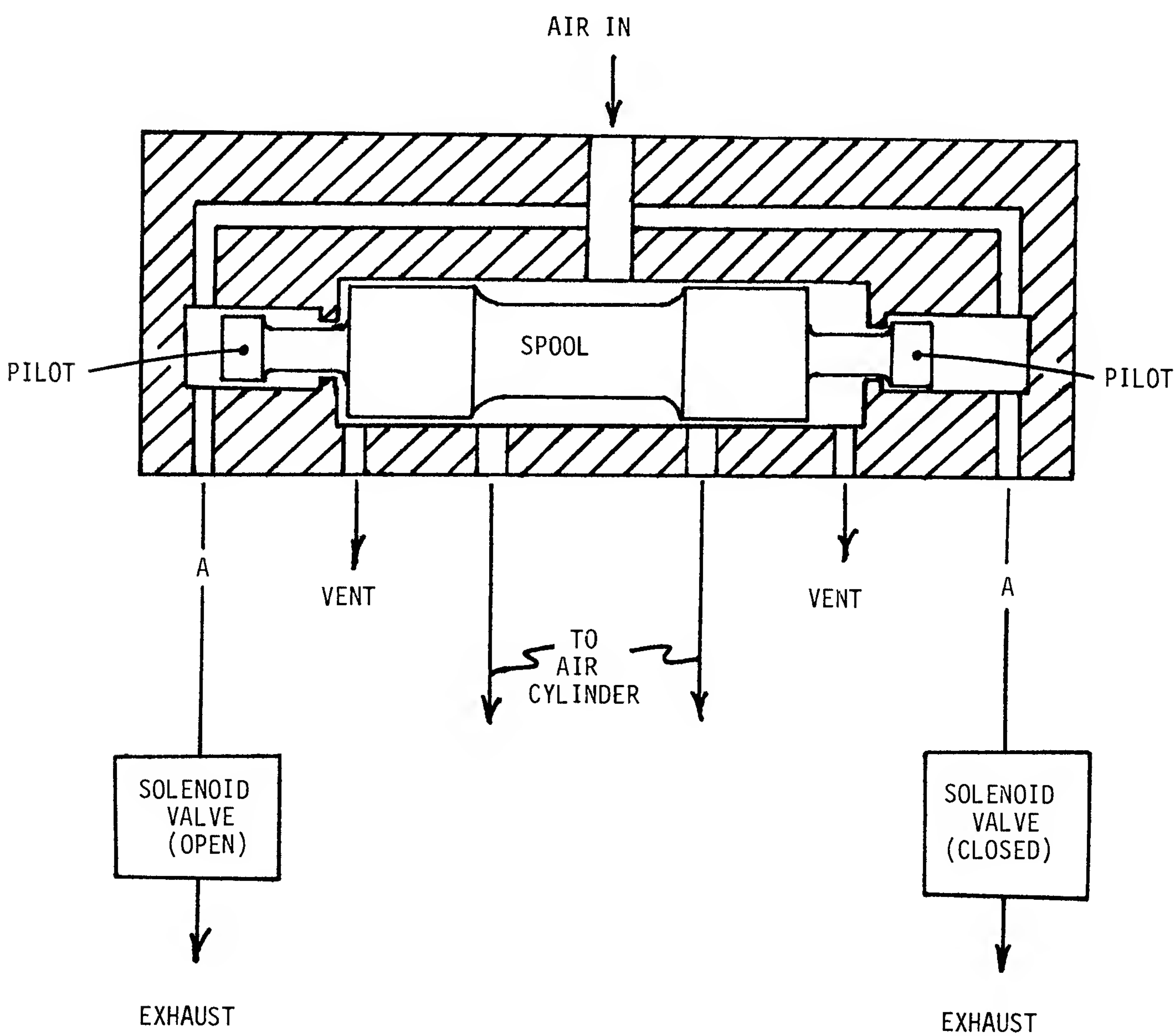


[2]Just ahead of the normally closed solenoid valve in the schematic diagram.

[3]This is provided by the normally open solenoid valve installed on a tee ahead of the 4-way valve. When the microswitch between the cradles is off (i.e., when no tube is in place), this valve is open, venting the line to the atmosphere. Closing the microswitch closes the valve, allowing the air cylinder on the vase jaw to be pressurized.

for a pilot-operated valve,[4] for example. It would be easier to use a 4-way solenoid valve, but we already had the pilot-operated valve."

[4]A pilot-operated valve has a spool similar to the 4-way valve described in Section G. But instead of being moved by a handle (or a solenoid) the spool is itself moved by air pressure. The position of the spool is controlled by the two solenoid valves shown attached to either end of the valve body in the circuit diagram. Each of these solenoid valves exhausts to the atmosphere. When the one on the left is open and the one on the right closed, as shown below, the valve spool is moved to the left by air pressure (acting on the pilot). Reversing both valves moves the spool to the right. The spool position controls the air cylinder for the beader wheel. The two solenoid valves are actuated by the timer. Note that the microswitch on the die head also interfaces with the time rather than directly with any of the valves.



Leonard worked on this project over a period of about a month, but was also doing other things; he estimated that he spent a total of about a week's time on the tube beader. "After it was done, Pat trained on it for a week" Leonard said. "He still had to show that he could make 1100 parts per day to keep up with the production schedule. This proved to be no problem--it was obvious that Pat had good motivation and wanted to work. He also had good stamina. Around the first of the year, he was taken on as a regular employee. Since that time the tube beader has worked fine as far as the modifications go. But we have had to keep an eye on wear of some of the moving parts--they probably see more force and more impact with the air cylinders than from manual operation. About the only change I've made was to add an adjustable plate to one of the cradles[5] because the tubes weren't being aligned or held very well and they moved around in Pat's hand. This was poor quality control on my welding job--the adjustable piece puts the rear cradle where it should be been in the first place."

The completed tube beader, set up for production, is shown in Exhibit K-1. The hopper for the tubes is in the background, a tub for the beaded tubes to the right.

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[5]This is visible in Exhibit G-3.

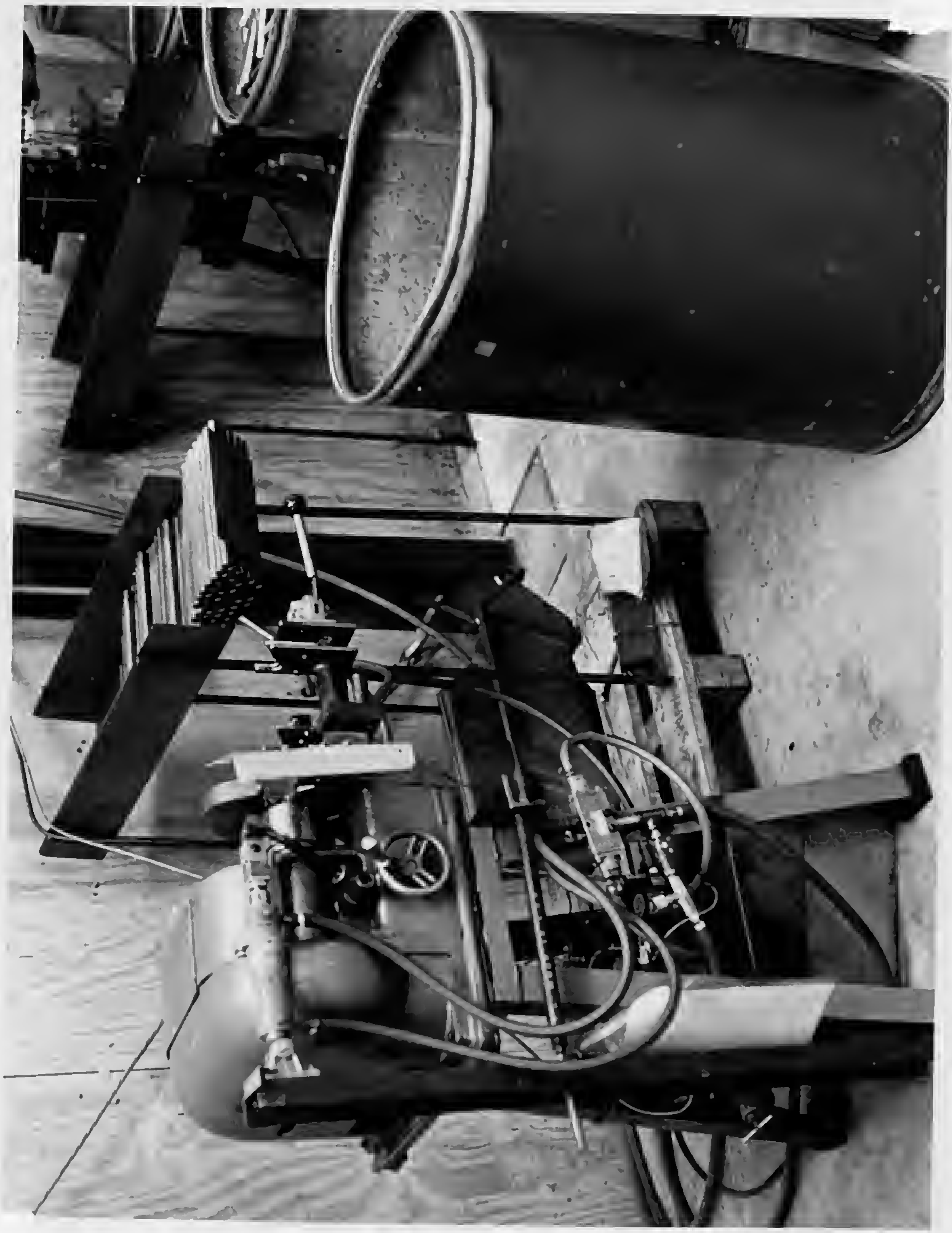

Exhibit K-1. Modified Tube Beader as Used in Production.